UNIVERSITY COLLEGE OF WALES

ABERYSTWYTH

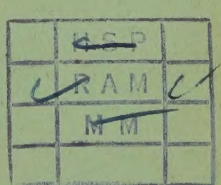
REPORT

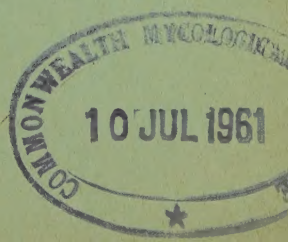
OF THE

WELSH PLANT BREEDING STATION

FOR

1960





WELSH PLANT BREEDING STATION
ABERYSTWYTH

REPORT

FOR

1960

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1961

SIR REGINALD GEORGE STAPLEDON
C.B.E., M.A., D.Sc., F.R.S.

Agricultural scientists the world over will mourn the passing of our first Director, Sir George Stapledon, on 16th September 1960.

A Memorial Service was held at the Welsh Plant Breeding Station on 21st October, at which The Rt. Hon. Earl Waldegrave gave the Address and Professor P. T. Thomas an Appreciation. In the old stone barn at the Station his friends and former colleagues thus paid their humble tribute to a great man, but it was not a last tribute, for wherever grass is grown as a crop we have a perpetual memory of a great scientist, a great pioneer, and a great friend with whom at all times it was a privilege to be associated.

Through the generosity of The Rt. Hon. Lord Milford, J.P., LL.D., Sir George Stapledon was able to establish the Welsh Plant Breeding Station in 1919, and he continued as Director until 1942 when the Government claimed his services as part of the war effort to increase food production. The whole pattern of research work at the Station has developed naturally from his pioneer work, and is in a large measure due to his vision and foresight.

In spite of Sir George's achievements as ecologist, agronomist and plant breeder, he would prefer, with typical modesty, to remain an outdoor biologist with the field as his laboratory. He was dedicated to a problem rather than to a particular science, and that problem was the improvement of land and the welfare of all who live by the land. To him it was the problem that mattered, but he appreciated that it could be effectively studied only through active and purposeful co-operation between a number of scientific disciplines, or, as he put it, by the mixing of the sciences. Here then we had the perfect combination of the scientist and the common sense practical man — a complete harmony of personality and policy.

The reclamation and rehabilitation of mountain and hill land were very near to his heart, and to that end he devoted his days ' in a spirit of unadulterated and unhampered enquiry '. To him every small plot, from the preliminary ' scratchings ' on the slopes of Plynlimon to the more detailed studies at the Cahn Hill-Improvement Scheme, was a ' gigantic experiment ' and a tremendous act of faith. He worked vigorously to find out what was possible, and from this to ascertain what was practicable, and ultimately to prove that it was also profitable.

Sir George Stapledon's outstanding contribution to agricultural science is universally acclaimed, but a full appreciation of his life and work must await the publication of a biography which would record his exceptional qualities both as a man and a scientist.

By courtesy of The Farmers Weekly

SIR R. GEORGE STAPLEDON, C.B.E., M.A., D.Sc., F.R.S.
1882 - 1960

First Director of the
Welsh Plant Breeding Station

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DIRECTOR'S REPORT

Developments in research

The nutritive value of herbage grasses

The objective in grass breeding is to produce varieties which will efficiently convert solar energy and soil nutrients into the type of herbage most needed for animal production. Thus while bulk of herbage is important its nutritive quality deserves equal consideration. Increasing attention must, therefore, be given to a physiological and biochemical approach to the breeding of our herbage plants.

The conversion of solar energy demands, on the one hand, the optimum amount of leaf area per acre for the interception of light, and on the other, a high level of photosynthetic efficiency per unit area of leaf. Dr. Cooper reports (p. 17) appreciable genetic variation for leaf production both between and within grass varieties, but remarkably small differences in photosynthetic efficiency when light intensity is adequate. However, under conditions of low light intensity which occur during certain periods of the year, and for the lower leaves in a dense sward, differences in photosynthetic efficiency assume greater importance.

The nutritive value of herbage depends in the first place on the proportion of it which can be readily digested by the animal, and secondly, on the constitution of this digestible portion. Work at Hurley and elsewhere has clearly shown differences between varieties, and now we are able to report considerable plant-to-plant variation, not only in digestibility but also in such important constituents as soluble carbohydrates.

To demonstrate genetic variation in nutritive characters is an important step in the development of improved varieties, but the breeder still needs to know which particular nutrients are of most value to the animal. Again, do we need the same kind of herbage for milk production as for beef? A great deal of attention has been given to protein, perhaps to the neglect of available carbohydrates and other constituents. In order to guide the grass breeder Dr. Cooper is establishing a number of single-genotype swards each derived by vegetative propagation from a physiologically-different individual plant. These swards will be used for nutrient assessment

trials using live-stock. The Station has now developed a small animal nutrition unit which will enable comparisons to be made with laboratory assessment for nutritive value.

Seed potential

In breeding herbage varieties with superior agronomic and nutritive characteristics it is essential to maintain a satisfactory seed potential, otherwise supplies will not be available to the farmer at an economic price. Experience has already shown that the persistent late-flowering pasture varieties have a lower seed potential than the less persistent early-flowering types (p. 64), and that commercial short-lived types have a higher pollen and seed fertility (p. 79).

Intensive selection for extreme times of flowering results in a general decrease in fertility in subsequent generations (p. 79), but of considerable interest to the breeder is the fact that some plants remain fertile even after six generations of selection. Breeding for superior agronomic characters, therefore, need not necessarily be accompanied by reduced seed potential, provided parallel selection for fertility is also practised.

Stability of herbage varieties

Herbage plants are out-pollinators, and therefore varieties often contain much hidden variation although they may look uniform when grown as single plants without competition. For this reason varieties can sometimes respond quite markedly to selective influences, either during seed multiplication or even in sown leys. Consequently, for the production of authentic seed which will produce a sward as envisaged by the breeder there must be rigid control at all stages from the breeder's Foundation Seed to the Certified Seed sown by the farmer. Based on principles and techniques which have been evolved at the Welsh Plant Breeding Station to safeguard the identity and characteristics of the varieties Mr. Gwilym Evans has shown (p. 82) how the organization for seed production and authentication has developed in this country. This contribution is appropriate in this F.A.O. World Seed Campaign and International Seed Year in which the objective is to further the use of high quality seed of improved crop varieties.

The selective influences of management on a herbage variety also operate in the sward (p. 99) and will determine its constitution. Only those genotypes which are best adapted to a particular system

of management will survive and contribute materially to the productivity of a sward. Thus in order to realize the full potential of a variety which has been bred for a particular purpose the sward must be managed in such a way as to encourage the genotypes characteristic of the variety. Mismanagement will tend to eliminate these valuable genotypes and allow the ingress of less desirable plants.

Plant introduction

For the normal season of growth the breeders at the Station have found that in general indigenous plants already adapted to conditions in this country provide the most satisfactory material as the basis for new varieties. Extension of the grazing season, however, requires plant material with different growth characteristics which can best be obtained from a wider geographical area. Great Britain is situated more or less between the winter-dormant areas of Northern Europe and the summer-dormant conditions of the Mediterranean. Plant introductions from more southerly areas have been found to possess increased winter growth without excessive summer dormancy, and new varieties of ryegrass, tall fescue and cocksfoot based on such introductions will be released when sufficient seed is available.

Of particular interest is a diploid form of cocksfoot from Portugal described by Dr. Borrill (p. 107), which is a primary source of vigorous winter herbage. It is very promising and gives twice the dry matter production of standard tetraploid varieties between October and January. Its production at other times of the year also compares reasonably well with established varieties.

Dr. Borrill has also produced a tetraploid form of this cocksfoot which will now enable the breeder to combine its characteristics with material selected from standard tetraploid cultivars.

A new tetraploid variety of cocksfoot developed by Mr. Beddows from material collected in south-west France will shortly be released for seed multiplication. It provides early spring keep, beginning active growth during March in advance of any other variety of cocksfoot at present on the market.

Other activities

Staff

Dr. Keith Jones resigned to take up the appointment of Cytologist at the Royal Botanic Gardens, Kew, Richmond, Surrey. Mr.

Ieuan Davies, M.Sc., was transferred from Grassland Agronomy to Grass Breeding. The following appointments were made : Mr. Hugh Thomas, B.Sc., to Cereal Breeding and Dr. D. I. H. Jones to Chemistry.

Dr. J. P. Cooper and Mr. W. T. H. Peregrine were awarded the M.Sc. degree, University of Wales.

During April the Director visited Portugal to explore sources of basic material for use in the breeding programme, and to make contact with workers in that country who could supply seed.

The following members of staff visited research institutions in Europe with the aid of travel grants awarded by the Agricultural Research Council :

Mr. D. Gareth Jones — Sweden and Netherlands
Mr. E. J. Lewis — Netherlands and West Germany
Mr. J. L. Stoddart — Norway, Sweden, Denmark and Netherlands

During the summer Dr. Martin Borrill visited S.W. Ireland to collect wild ecotypes of *Dactylis* spp., for use in the grass breeding programme.

Visiting research workers

Mr. J. Sithamparanathan, a British Council Scholar from Ceylon, is continuing his post-graduate research work on agronomic studies on Yorkshire fog for hill land.

Mr. D. M. Calder, M.Sc., Massey Agricultural College, Palmerston North, New Zealand, commenced his post-graduate studies in January 1960, on ' The control of flowering in certain herbage grasses ' with a view to presenting a thesis for the degree of Ph.D. University of Wales.

Post-graduate students

Mr. K. J. R. Edwards, University of Reading, an A.R.C. Research Scholar, is continuing his research on ' Leaf development in ryegrass '.

Mr. L. Beevers, University of Durham, working with the aid of

a special A.R.C. grant in the Department of Agricultural Botany, U.C.W., continued his work on 'The biochemical assessment of different genotypes of herbage grasses in relation to their physiological characters'.

Visitors

In the year under review the Station was again visited by numerous individual persons and organized parties from Great Britain and overseas. The countries represented were Argentina, Australia, Belgium, Brazil, Canada, Colombia, Costa Rica, Denmark, Egypt, Finland, France, Germany, Ghana, Holland, Honduras, India, Iraq, Ireland, Israel, Italy, Jamaica, Japan, Kenya, New Zealand, Pakistan, Poland, South Africa, Sweden, Tanganyika, U.S.A., U.S.S.R., West Indies, Yugoslavia.

Amongst the organised parties we were pleased to welcome 155 members of the Seed Trade Association of U.K., with their President Mr. W. I. Bryant. This was a particularly happy occasion as it was in 1931 that the Association last visited the Station. We also had the N.A.A.S., Advisory Entomologists (34), N.A.A.S. Yorks. and Lancs. Province (28) and Northern Province (20), the Welsh Agricultural Organisation Society Co-operative Managers (10), the Welsh Seed Growers' Association (65), Milk Marketing Board Regional Members (12), the Celtic Congress (90), the Aberystwyth Seeds Committee and the Development and Education Committee of the National Farmers' Union.

The Honours Agricultural Botany, Dairy Diploma and other students of the University College of Wales, Aberystwyth, together with students from Farm Institutes, and from the Training Colleges at Bristol, Stafford, Padgate and Derby, also from Bedford College, London, and the University of Southampton, were received at the Station. We were also pleased to welcome members of branches of the N.F.U., and of Discussion Groups from various parts of the country.

In connection with the Eighth International Grassland Congress held in Reading we received members on the Farming and Advisory Tour (29), who were entertained to dinner by His Worship the Mayor of Aberystwyth, Alderman H. Ifor Owen, J.P., and on the Research Tour (57), who were entertained to dinner by the Principal of the University College of Wales, Dr. Thomas Parry, M.A. In

addition, a large number of delegates to the Congress visited us individually before and after the Congress.

We were also glad to receive The Rt. Hon. Christopher Soames, P.C., C.B.E., M.P., Minister of Agriculture, who was particularly interested in the work of the Station ; Mr. Harold Woolley, C.B.E., President of the National Farmers' Union, Lord Netherthorpe, Dr. Stepanov, Soviet Embassy, London, and Academician Professor Dr. Ivan V. Larin, Leningrad, amongst other distinguished visitors.

Conferences and lectures

Six members of staff read papers at the Eighth International Grassland Congress in Reading, and others were at the various sessions.

During the year members of staff attended meetings and read papers to the Genetical Society and other learned bodies. The usual Herbage Seed Inspectors' Course for Trainees, and the Refresher Course for Cereal Seed Crop Inspectors, were well attended. We also provided a three-day course for members of the Institute of Corn and Agricultural Merchants, which was much appreciated by the large number present.

Dr. Martin Borrill, Dr. E. L. Breese, Dr. J. P. Cooper and Mr. D. M. Calder attended the Ecological Genetics Group at Ottingham Park, Shrewsbury, which was organized by the Nature Conservancy.

A Herbage Seed Production Conference was held in Norwich in November 1959, at which Mr. H. M. Roberts gave an address on ' The effect of cutting or grazing on the seed potential of grass seed crops '. A good discussion followed. Mr. Roberts also lectured to the East Riding of Yorkshire Farmers' Club at Beverley on ' Seed production methods ', and to the Lincolnshire Seed Growers' Association on ' The effect of grazing and cutting on seed yields of leafy varieties '.

Mr. W. Ellis Davies addressed the Honey Producers Association of Great Britain on ' Clovers — with particular reference to the relation of clover breeding to the honey bee '.

Dr. Alice Evans lectured on ' Sources of pollen and honey in plants of the Aberystwyth District ' to the Aberystwyth Beekeepers' Association.

Mr. T. D. Johnston gave a lecture to the Hay-Talgarth Seed Growers' Association on ' Breeding improved kales and rapes '.

Talks were given to the scientific staff by the following visitors : Mr. Albert Davies, N.A.A.S. (Wales) ; Dr. A. D. Bradshaw, U.C.N.W., Bangor ; Mr. Roy Hughes, Hill Farming Research Organisation, Edinburgh ; Professor M. B. Tessar, Michigan State University, U.S.A., and Dr. J. Griffiths Davies, Brisbane, Australia.

Members of staff continue to give lectures to the Honours Agricultural Botany students of the College.

At the request of Messrs T. B. Lock, Yeovil, who were responsible for the ' British Certified Seeds Exhibit ' at the Bath and West Show held at Bath in June 1960, the Grass Breeding staff supplied special material consisting of plants of *L. perenne* to illustrate the breeding techniques of cross-pollination and selfing.

The Station, in collaboration with N.A.A.S. (Wales), has been consulted by the Central Electricity Board, and by the local Planning Authority, in regard to reseeding sites disturbed by the new Hydro-Electric Scheme in North Cardiganshire.

A botanical survey of the lands of the N.A.A.S. (Wales) Experimental Husbandry Farm, Pwllpeiran, was carried out under the direction of Mr. Ll. Iorwerth Jones.

Some phases of the work of the Station have been demonstrated on T.V., by arrangement with the B.B.C., and also on sound for the European and Overseas Services of the B.B.C.

Acknowledgements

We wish to thank Dr. P. S. Nutman, Rothamsted Experimental Station, Harpenden, Herts., for the facilities granted to Mr. D. Gareth Jones when visiting the Soil Microbiology Department.

We are grateful to numerous firms, organizations and individuals who have supplied seeds, plants, chemicals and insecticides for experimental purposes.

We are glad to place on record our appreciation of the collaboration of the staffs of the National Agricultural Advisory Service; National Institute of Agricultural Botany; Forestry Commission; the Hill Farming Research Organisation, Edinburgh; Grassland Research Institute, Hurley; the Royal Botanic Gardens, Kew, and of the Institute of Rural Science, U.C.W., Aberystwyth.

In addition we thank the following who have generously provided land for special experiments: Capt. G. L. Bennett Evans, O.B.E., M.Sc., Manod, Llangurig; Mr. H. E. Williams, Bwlch-Crwys, Devil's Bridge; the N.A.A.S. (Wales) Experimental Husbandry Farm, Pwllpeirian; Mr. Dan Davies, Llety Ifan Hen, Bontgoch; Mr. J. B. Stevens, The Firs, Moortown, near Wellington, Shropshire; Mr. H. Nicholas, Sutton Farm, West Felton, near Oswestry, and Mr. W. Morgan, Tynrhyd, Devil's Bridge.

Special thanks are due to Miss Irene D. Rees for her painstaking work in compiling this report and for seeing it through the press.

DEVELOPMENTAL GENETICS

J. P. Cooper

Work has continued on the genetics and physiology of agronomic characters in the herbage grasses, special attention being given to the control of flowering, to leaf and tiller development and associated changes in carbohydrate and nitrogen metabolism, and to varietal differences in mineral uptake and utilization.

Selection for date of ear emergence in *Lolium* (J.P.C.)

Selection for early and late ear emergence in Irish and Kent ryegrass has produced rapid and continued response for six generations although without any appreciable decrease in the between-plant variance within the selection lines. The selection differential is similar in both directions, but the realized heritability is always higher in the late lines.

Selection for ear emergence in Lolium perenne *L.*

	Selection differential (days)	*Response (days)*	*Realized heritability Per cent*
Irish			
Early	–45.0	–15.0	33
Late	+39.6	+27.1	68
Combined	84.6	42.1	50
Kent			
Early	–52.6	–32.3	62
Late	+60.7	+47.5	78
Combined	113.3	79.8	71

The selection differential and realized heritability are higher in Kent than in Irish, possibly because of less stringent agronomic selection in the past. Back-selection, which was started in each line after the first generation, indicates that considerable potential genetic variation can be carried within four foundation plants.

Male and female fertility were high in the original varieties, though lower in Kent than in Irish, but by the sixth generation of selection, fertility has declined in all lines, and in some instances

severely reduced the possible selection differential. The variation in fertility *between* and *within* plants was increased in the selection lines.

There were no regular correlated responses in such seedling characters as leaf size, rate of leaf appearance, tiller number, dry weight per plant or per tiller, and although the mating system involves moderate inbreeding, in only 5 out of 10 cases was there slight depression in these criteria of vigour. The actual level of inbreeding in these lines is evidently rather less than that expected on theoretical grounds.

Flowering responses in *Dactylis* (D.M.C.)

The flowering reaction in ryegrass is based on a winter requirement for either cold or short-day for floral induction, followed by long photoperiod for floral initiation and subsequent development. Neither plant spacing nor nitrogen level appear to have appreciable effects on the course of inflorescence development.

In cocksfoot the flowering requirements are more complex. Cocksfoot has been reported to have an obligate winter requirement for floral induction, but in certain varieties some or all of the seedlings can head after an April or May sowing, i.e. without either cold or short-day exposure. There are marked population differences

Heading in Dactylis *populations after spring sowing*

Origin	*Sowing dates*		
	1st April	*1st May*	*1st June*
	Per cent heading		
Portuguese diploid	100	100	20
Tunisia	50	65	0
Palestine	50	60	5
Akaroa	35	20	5
N.Z. Grasslands	10	5	0
Aberystwyth S.37	35	20	0
„ S.143	20	10	0
„ Early Fodder	35	15	0
Norwegian	55	20	0
Danish	55	10	0
Roskilde II	40	15	0
Swedish late	0	0	0

in this respect. The most profuse heading occurred in the Portuguese material, and the least in a late Swedish variety, but the correlation between degree of heading and climatic origin was not complete.

It has not been possible to accelerate floral induction by artificial cold or short-day treatment given separately or in combination to the germinating seed or the young seedling. Compared with outdoor temperatures and long photoperiods, high glasshouse temperatures and continuous light appear to have an inhibitory effect on floral initiation. Plant spacing and nitrogen level, however, have an overriding effect on floral initiation in this species. After an April sowing, 87.5% of the Palestine variety, and 37.5% of the S.143, initiated heads at wide spacing and high levels of nitrogen, but at dense spacing and low levels of nitrogen only one plant (of S.143) out of 80 produced heads.

Work is continuing in both cocksfoot and ryegrass to elucidate the effects of spacing and nutrition on flowering which may have important implications in the management of pastures either for seed production or for continued leaf production.

Leaf and tiller development in *Lolium*

In the past year attention has been concentrated on the development of leaf area as a determinant of yield, and swards of single genotypes have been established for this purpose. The seasonal changes in leaf area, tiller number and nutritive value will be recorded throughout 1961. Techniques are also being established to compare the efficiency of photosynthesis in different genotypes using labelled CO_2.

Growth analysis (K.J.R.E.)

Growth analyses of three perennial ryegrass varieties, Italian, Irish and Hunsballe, show that in the early seedling stage, up to a leaf area index (LAI) of about 2, variation in dry matter production is based almost entirely on leaf area, there being no significant difference in net assimilation rate (NAR) between varieties. At a later stage, however, when the leaf area index has risen to 3–5, a more complex picture is revealed, with varietal differences in both LAI and NAR. The variation in NAR may be based on differences in leaf angle between the varieties ; Irish is rather prostrate at this stage, while Italian and Hunsballe are more erect.

Several pair-cross families within each variety were analysed at the late seedling stage. Significant family differences were

found in Italian and Hunsballe, but not in Irish. These family differences *within* varieties were based largely on variation in leaf area, no variation in NAR being detected.

Selection for a rapid increase in leaf area may thus be a useful approach to improving yield, bearing in mind that the density-dependence of NAR may become important in later stages.

Selection for leaf components (J.P.C., K.J.R.E.)

Selection for leaf size and rate of leaf appearance in Italian, Irish and Hunsballe ryegrass has now continued for three generations, and selection has been started for total leaf area. The heritability estimates derived from the first generation progenies no longer provide useful predictions of the degree of response, but the genetic correlations give a good indication of the correlated responses to be expected. Selection for leaf size, for instance, continues to result in an inverse correlated response in rate of leaf appearance, but greatly increases dry weight/tiller. The original varieties and the second generation selection lines have been grown

Selection for leaf size in ryegrass : 3rd generation

	Italian			*Irish*			*Hunsballe*		
	High	*Low*	*Diff.*	*High*	*Low*	*Diff.*	*High*	*Low*	*Diff.*
Leaf size (mm.²)	1849	955	894	1208	516	692	1090	746	344
Selection differential (mm.²)	—	—	2606	—	—	1245	—	—	1562
Realized heritability (per cent)	—	—	34	—	—	55	—	—	22
Rate of leaf appearance (days/leaf)	16.6	10.8	—	9.0	7.3	—	10.4	8.3	—
Dry wt./tiller (mgm.)	76	39	—	45	19	—	43	37	—

in water culture at two levels of nitrogen (84 and 14 ppm.). In general, the high nitrogen level increased leaf size and accelerated leaf appearance, but there was appreciable family/nitrogen level interaction for both characters. Furthermore, the effect of nitrogen operated through leaf length in some lines and through leaf width in others. The developmental effects of nitrogen nutrition on cell size and number are being studied in this material.

Cell pattern in the developing leaf (J.P.C., M.A.F.)

The pattern of cell size and cell number has been studied in the three parent varieties, Italian, Irish and Hunsballe, and in the second generation selection lines for leaf size. There is little difference in leaf dimensions between the perennial varieties, although the cells in Hunsballe are larger than in Irish, its leaves contain fewer of them. Italian ryegrass has longer and wider leaves than perennial ryegrass but this increase is based entirely on a larger number of cells, the cells themselves being invariably shorter and narrower.

Cell pattern in selection lines of ryegrass

	Leaf length (mm.)	*Cell length (μ)*	*No. of cells in length*	*Leaf width (mm.)*	*Cell width (μ)*	*No. of cells in width*
Italian						
High	360	618	583	6.3	20.2	311
Original	242	494	495	5.1	20.5	249
Low	189	504	376	4.7	18.7	249
Irish						
High	235	653	360	3.9	21.1	187
Original	213	627	339	3.8	20.8	183
Low	208	614	339	3.4	20.7	167

Selection for leaf size can operate through leaf width or leaf length or both, and at the cell level either cell size or cell number can be changed independently.

In Italian, for instance, the increase in width of the high line is based almost entirely on a greater number of cell rows ; the decrease in the low line is due to narrower cells, but the number of cells remains the same. In Irish, however, the low line shows a decrease in cell number without any alteration in cell width. The same gross changes in leaf size can evidently be obtained from many different combinations of cell pattern, and it is not surprising that leaf area shows marked family and varietal interactions with such environmental factors as light intensity, temperature and nitrogen level.

Biochemical variation (L.B., K.J.R.E.)

The analysis of individual genotypes of cocksfoot and ryegrass (kindly carried out by Dr. J. M. A. Tilley, Grassland Research Institute, Hurley) has revealed large differences *between* and *within*

varieties for *in vitro* digestibility and soluble carbohydrate content.

The pattern of leaf development and associated changes in carbohydrate and nitrogen fractions have also been studied in four contrasting ryegrass families grown under controlled light and temperature conditions. These included day and night temperatures of 25°-25°C, 25°-12°, 12°-25°, and 12°-12° respectively, with high (1500 ft. c.) and low (700 ft. c.) light intensities. Both leaf width and length were decreased by high night temperature, while high day temperature decreased the width but increased the length, thus leading to differential effects on leaf size.

Rate of leaf appearance was accelerated by an increase in either day or night temperature, but night temperatures had a greater effect in Irish than in Italian. Total leaf number, however, was considerably higher in the 25°-12°C. treatment, due to an inhibitory effect of high night temperature on tiller number.

Total leaf area presents a complex picture, since its components are differentially affected by light and temperature. In general, the highest figure was obtained from the 25° - 12° treatment but marked family interactions occur in the relative effects of the 25°-25° and 25°-12° temperature regimes, based largely on differences in tiller development.

High light intensity decreased leaf size considerably, mainly through leaf length, but the rate of leaf appearance and tiller number were greatly increased, giving a much higher total leaf area per plant.

Although environmental effects were most obvious, significant family differences were obtained for all the leaf components, but marked family/treatment interactions occurred for leaf length, rate of leaf appearance, total leaf number and total leaf area.

The biochemical composition also was strongly influenced by light and temperature.

Soluble carbohydrate content in ryegrass families under different temperature regimes

		25°-25°C.	25°-12°C.	12°-25°C.	12°-12°C.	*Mean*
Italian	A	5.17	4.72	5.66	10.77	6.58
	B	5.40	5.67	6.17	10.15	6.85
Irish	A	4.39	4.62	6.06	9.58	6.16
	B	3.81	4.56	4.66	9.80	5.71
Mean		4.69	4.89	5.64	10.08	

L.S.D. of means at 5% = 0.47

The highest percentage of soluble carbohydrate, for instance, was recorded in the 12°-12°C. treatment, but at the high day temperature, night temperature had no significant effect. High light-intensity, as was to be expected, increased the carbohydrate content. In spite of the marked treatment effects there were significant family differences for most of these biochemical constituents, including carbohydrate content. In these particular families rapid leaf appearance and narrow leaves seem to be associated with a low carbohydrate content. Marked treatment/harvest-date interactions, however, were detected for most components, probably due to differential shading at the later harvest dates, and this effect must be borne in mind in future selection work.

The physiology of the vegetative grass plant (P.B.V.)

With the continual production of new tillers and regrowth that is obtained with vegetative perennial ryegrass on frequent defoliation, the utilization of phosphorus must be important. Do vegetative plants require more phosphorus than flowering plants? Does the demand for phosphorus vary with nitrogen level or frequency of defoliation? Is there an increased uptake of phosphorus immediately following defoliation? Further study has answered a number of these points (Koontz and Vose, 1960).

The comparative uptake of phosphorus by flowering and vegetative ryegrass was studied in *Lolium temulentum* using a P^{32} technique. It was found that the vegetative plants produced more tillers, foliage and roots, and contained more phosphorus per unit dry weight than did flowering material of comparable age. The rate of phosphorus uptake was greater in the vegetative material than in the vernalized plants, and the rate of uptake declined more slowly with time.

The uptake of phosphorus in relation to defoliation and nitrogen nutrition was studied in *L. perenne*. Three nitrogen and two defoliation treatments were used. It was found that there was an increased demand for phosphorus immediately following frequent defoliation, or when infrequently defoliated plants were grown at a high nitrogen level. Infrequently defoliated plants grown under nitrogen-limiting conditions did not show increased phosphorus demand following defoliation.

An interpretation of these results may be made in terms of the increased dry matter and tiller production that is stimulated by high nitrogen nutrition on the one hand, and by infrequent cutting on

the other. Thus there was an increased rate of phosphorus uptake with a high rate of tiller regrowth such as occurs with frequent defoliation at any level of nitrogen, and also with the production of new tillers as a consequence of infrequent defoliation and a high nitrogen level. This increased rate which occurred immediately after defoliation may be ascribed to the higher phosphorus requirements of the newly differentiating and expanding tissues. The comparatively low rate of phosphorus uptake that occurred with infrequent defoliation at the lower nitrogen levels was probably due to a reserve of phosphorus having been built up in the rootstock following the nitrogen limitation of foliage growth. With high nitrogen there was no such limitation and the pattern of phosphorus uptake followed that of frequent defoliation.

It is apparent that uptake of phosphorus is closely linked with tiller production. Thus vegetative material of *L. temulentum* has a greater phosphorus uptake and content, and a higher tiller number, than unvernalized plants. With *L. perenne* the greatest rate of phosphorus uptake is either with frequent defoliation and consequent regrowth of tillers, or with infrequent defoliation and high nitrogen, giving rise to a high rate of new tiller formation.

Intraspecific differences in nutrient uptake and assimilation (P.B.V.)

Aluminium toxicity. The investigation continues of the use of resistance to aluminium toxicity as a selection index for persistence of *L. perenne* on acid soils in high rainfall areas. Whereas it was possible to achieve good initial selection for aluminium resistance between and within established varieties at a level of 50 ppm. aluminium, it was necessary when evaluating the F_1 progenies progressively to increase the concentration of aluminium to 200 ppm., and finally to cut the foliage back and to allow regrowth before good separation of resistant and susceptible progenies was obtained. Thus considerable increased resistance to aluminium toxicity can be achieved with only two generations of selection.

Cation content. The content of potassium, sodium, calcium and magnesium has been studied in twelve different varieties of *Lolium perenne*, grown on three soils of different calcium content and with pH varying from 5.1 to 7.2. The ratio $\frac{K}{Ca + Mg}$ reported to be important in the etiology of hypomagnesaemia was also calculated. It was found that there was variation in potassium content and $\frac{K}{Ca + Mg}$ ratio between varieties, and that the differences in ratio were greatest on the soil low in calcium. The differences in

cation ratio between varieties and soils were due to variations in all three elements, but the concentration of potassium was of most importance.

The varieties could not be ranked for all three soils either on the basis of potassium content or cation ratio, there were, however, certain consistent features. One variety had the highest potassium content for all three soils ; three varieties were low in potassium for all three soils ; two varieties had the consistently lowest $\frac{K}{Ca + Mg}$ ratio ; two varieties had the lowest calcium content.

Manganese. Studies in cereals (in co-operation with Dr. D. J. Griffiths, Cereal Breeding) are principally intended to shed light on susceptibility to manganese deficiency and the grey speck syndrome in *Avena*. The possibility of selecting breeding material resistant to the grey speck syndrome is complicated by the fact that it is not yet certain whether the known variation in resistance is due directly to manganese deficiency, or whether the deficiency functions indirectly by rendering the roots more susceptible to infection by rhizosphere organisms.

Manganese and magnesium content of oats susceptible and resistant to grey speck disease

		Per cent			
Manganese		*Manganese*		*Magnesium*	
treatment (*ppm.*)	*Variety*	*Roots*	*Leaves*	*Roots*	*Leaves*
0	Star	0.00050	0.00050	0.45	0.55
	S.171	0.00256	Trace	0.29	0.35
0.1	Star	0.00098	0.00175	0.44	0.50
	S.171	0.00300	0.00044	0.30	0.57
0.2	Star	0.00240	0.00200	0.46	0.45
	S.171	0.00350	0.00048	0.06	0.26
0.5	Star	0.00250	0.00800	†	0.27
	S.171	0.00500	0.00440	0.05	0.22
2.0	Star	0.00253	0.02000	0.25	0.35
	S.171	0.01250	0.01920	0.05	0.22
5.0	Star	0.00150	0.03900	0.23	0.48
	S.171	0.01350	0.02800	0.07	0.42

†No data

Current investigation has been concerned with possible differences in the critical levels of manganese in tissues of varieties of oats susceptible and resistant to grey speck. The susceptible variety Star and the resistant variety Aberystwyth S.171 have been grown in sand culture with six levels of manganese, 0.0, 0.1, 0.2, 0.5, 2.0 and 5.0 ppm.

The results in the table show that for mature plants at the lower manganese levels the manganese content of the leaves of Star is consistently higher than that of S.171, but with manganese treatments of 2.0 and 5.0 ppm. there is no significant difference. The reverse holds for the manganese content of the roots, as in every instance S.171 has the high manganese content, the difference between the two varieties being greatest at the highest manganese concentrations.

The variety S.171 contains less magnesium in the roots at all manganese levels than Star, but both varieties show a decrease in magnesium content when the manganese supply changes from limiting to adequate. The difference in the magnesium content of the leaves, however, is not so marked, the decrease being most significant in S.171.

If at maturity manganese passes from shoot to root then the higher manganese of the roots and the lower content of the leaves in S.171 may reflect the greater mobility of manganese in this variety. The comparative lack of mobility of manganese in Star is then indicated by the high-leaf/low-root manganese concentrations, due to retention of manganese in the leaves without redistribution to the roots. Taking this view, susceptibility to the grey speck syndrome might be due to lack of mobility of manganese within the plant. An alternative hypothesis is that the grey speck resistance of S.171 may be due to the comparatively high concentration of manganese in the roots inhibiting the invasion and multiplication of ammonium-forming rhizosphere organisms. More effective mobility of manganese seems more likely to be the basis of superior grey speck resistance, in that the syndrome appears to be primarily a disorder of photosynthesis, with root deterioration as a secondary factor.

Further data have shown that there are also considerable differences in the leaf and root concentrations of the calcium, phosphorus and potassium in certain cereal varieties grown under the same conditions in sand culture.

Calcium, phosphorus and potassium content of cereal varieties

	Ca		*P*		*K*	
	Leaves	*Roots*	*Leaves*	*Roots*	*Leaves*	*Roots*
Wheat						
Koga II	1.95	0.52	0.37	0.23	0.91	0.80
Atle	1.31	0.36	0.36	0.16	0.91	0.32
Oats						
Star	1.70	0.50	0.71	0.36	1.10	0.71
S.171	2.22	0.58	0.51	0.23	0.95	0.49
Letoria	2.05	0.63	0.41	0.23	0.42	0.50

Major differences are of interest here and in the oat varieties these include the very low concentration of potassium in the leaves and roots of Letoria, compared with Star, while Letoria also has a comparatively low phosphorus concentration in the leaves. In wheat, Atle has a much lower calcium content of leaves and roots than Koga II, while the root concentration of both potassium and phosphorus is also much lower. What these differences mean in terms of yield and fertilization requirements is not yet known, but it is probable that varietal differences such as these cannot be ignored in breeding for high production.

GRASS BREEDING

A. R. Beddows

The breeding system in *Holcus lanatus* (A.R.B.)

Yorkshire fog is a diploid perennial herbage plant indigenous throughout the United Kingdom. The emergence of the panicles takes place during May and June, and they flower in June and July. Anthesis occurs twice each day if weather conditions are favourable and stable. The first exsertion of anthers and stigmas begins about 5 a.m. G.M.T., and the second from about noon. Each spikelet has two florets, the lower of which is hermaphrodite, and the upper male, but occasionally the latter may also become hermaphrodite, functionally female and produce a viable caryopsis.

Cross-pollination is almost obligatory and self-fertilization is limited, far more so than is usual in other species. The majority of the plants tested for self-fertility gave nil, or only a fractional percentage of viable caryopses. The maximum self-compatibility was 20 seedlings per 100 spikelets.

The inbred populations contained various types of mutants and of these the lethal yellow and lethal pale green were of special interest, as the recessives *yy* or *gg* appear to inhibit anthocyanin development. Another unusual and rare mutant was the dwarf green; plants of this formed dense rosettes with short, broad, relatively dark green leaves. The most vigorous attained a diameter of about 6 cm. after six months' growth.

Non-anthocyanin normal greens are occasionally found in nature. These non-reds fall into two groups, and when crossing is confined to within a group all the progeny are anthocyanin-free.

The appearance of the reddish colouration on the veins of the sheaths and on the glumes is dependent on the presence of two major complementary genes.

Studies in self- and cross-fertility and seedling leaf length in *Lolium perenne* (A.R.B., E.L.B. and B.C.†)

Variation in the ability of basic plant material to set seed on selfing, particularly on crossing, is important for it will condition the average seed production of any varieties produced by inter-pollination, and determine the proportion of progeny from each basic plant after a given number of generations of seed-multiplication. A consideration of the cross- and self-fertility of potentially useful

†Dr. Betty Lewis (née Cocks), who is no longer on the staff of the Station.

plant material should be, therefore, a prerequisite to the formation of synthetic varieties.

A study has been made of the relative fertility of eight genotypes of *Lolium perenne* selected as the basis of an early-flowering variety. Initial results are summarized below.

Selfing tests conducted over three years under glasshouse conditions demonstrated that the plants generally have a low self-fertility (5% seed-set or less). Within this range, however, there were significant differences between genotypes, consequently there exist possibilities of selecting more self-fertile lines should the occasion arise. A significant feature of the tests was a differential decline in seed setting as the age of the plants increased. In the past such senescence effects have not received much attention but they may well be important, especially in those perennial species where the basic plants of synthetic varieties are maintained vegetatively for many years. For instance, senescence effects leading to differential cross-fertility and other irregularities could well affect the proportions and type of seed derived from the different basic plants and so finally alter the constitution of the variety.

The 56 possible crosses between the eight plants were performed by hand-emasculation and hand-pollination techniques. Seed-setting was scored as the percentage of emasculated florets setting heavy seed and it was possible to analyse the data by the methods of Yates (*Heredity* 1, 287–301, 1947). The average percentage seed-set (42%) was much higher than that obtained under selfing but again there was significant heritable variation which in this instance could be unambiguously and solely ascribed to the influence of the maternal genotypes. There were no indications of specific incompatibilities which might denote the operation of an incompatibility locus (or loci) of the type found in clover and other species. Neither was there any correlation between the proportions of seed set under outcrossing and that set under selfing, so that evidently the system of control is not the same in both cases. It was not established whether the maternal effects occurred at pre- or post-fertilization stages, nor was it determined whether any of the parents exhibited cytological aberrations and associated meiotic irregularities. Nevertheless, the need for carefully screening parental material for differences in cross-fertility is emphasized and the results suggest that in so far as the differences appear to be mainly maternal this screening can be adequately accomplished by poly-cross, or even by open-pollination techniques.

The seed from the crosses was sown in boxes in the glasshouse, and 17–20 days after germination the length of the first seedling leaf was measured on the seedlings in each F_1 family. Analysis revealed significant reciprocal differences and these effects could again be ascribed to maternal influences. At the same time it was possible to distinguish differences which were specific to individual crosses, thus indicating that the zygote was beginning to exert some effect, but compared with the maternal influence this was still relatively unimportant. Thus early seedling development, which may well predispose the ability of the plant to establish under competitive conditions in the sward, appears to be a function of the maternal genotype. In the absence of a further generation, and therefore of the ability to distinguish between the contributions of maternal grandparents, it was impossible to say whether these effects depended on the maternal cytoplasm, the endosperm, or the maternal tissues of the seed. It is important, however, to elucidate further this type of control so that the final behaviour of synthetic varieties in this respect may be predicted from initial progeny tests.

Varietal identification : Cocksfoot (*Dactylis* spp.) (M.B.)

The identification of individual populations such as ecotypes, or cultivars, is difficult, and it is desirable to develop rapid techniques for separating them at the seedling stage. The epidermal pattern of leaf six on the main shoot was studied in six *Dactylis* cultivars. Twelve genotypes of each were grown randomized in three replicates. Various characters were studied, and it was found that all the varieties could be separated by using epidermal cell length and width in the leaf blade.

For positive identification to be attempted, cultivars would need to be ranked relative to the known performance of varieties grown as standards. Cell pattern shows sufficient promise to be worthy of further investigation, since seedlings are used and results can be obtained in about six weeks. A multiple screening technique could be developed, using a combination of epidermal cell size and heading response. At present this would have to be restricted to genera such as *Lolium* where the prerequisites for heading are known.

Intergeneric hybrids (E.J.L.)

Progeny deriving from a polycross of the fertile amphiploids of *L. multiflorum* × *F. arundinacea* reported earlier (Rep. 1956–58, p. 12) exhibited a range from very high fertility to almost complete

sterility. The most fertile plants showed normal anther dehiscence with pollen fertility of 80% and over, together with relatively good seed setting although it was low in comparison with that of the parental species.

Preliminary cytological examination revealed that low fertility in these cases is due to aneuploidy, brought about, on the male side at least, by the exclusion of univaleuts from the gametes at anaphase II of microsporogenesis, and presumably this also occurs at the same stage of megasporogenesis. However, one aneuploid, a plant with 34 chromosomes, was found to be highly fertile and on selfing has given a few seeds.

The 56-chromosome plants have been further multiplied through another generation and appear to maintain their good fertility, and are presumably stable at this chromosome number.

Small scale agronomic assessment will be commenced when enough seed becomes available.

Interspecific hybrids (I.D., E.J.L.)

A further programme of hybridization between *L. perenne* and *L. multiflorum* has been initiated with a view to producing a variety suitable for a four-year ley possessing improved autumn and winter performance. Plants of S.22, a variety of *L. multiflorum*, were crossed with plants from six varieties of *L. perenne*, Brabantia (hay type), S.24, S.101, S.23, Ba 6280 (which has good late autumn production), and Ba 6293 (which is winter green). The six populations of F_1 hybrids will be multiplied in isolation for the production of sufficient second generation seed for agronomic assessment.

Damage to grasses by shoot fly (*Diptera* spp.) (T.I.E.)

Larvae of the shoot fly (*Diptera* spp.) caused considerable damage to grasses at the Station during 1957 to 1959, and in order to examine the characteristics of the damage an experiment was superimposed on a trial already in existence relating to the growth of plants.

The late generation of the flies (oviposition from September onwards) caused the greatest damage to grasses, and the number of tillers killed was highest in late autumn and early spring. The larval attack which killed the main tillers increased the number of axillary tillers, but decreased the size of the leaves and tillers, and this reduced the yield. When overwintering tillers were lost, ear emergence was delayed and the number of flowering heads substantially

reduced. The single plants most exposed to damage were those with relatively few tillers per unit area.

Different species, varieties, and even different genotypes within a variety, show degrees of susceptibility to the damage and capacity to recover from it. Favourable growing conditions promote recovery and reduce loss. Suitable agrotechniques at the present time appear to give more useful protection on the field than does the use of chemicals. Plants in glasshouses, especially single tillers or seedlings, should be regularly sprayed during the winter. For this purpose a weekly application of Tritox, 0.7% conc., is favoured.

HERBAGE LEGUME BREEDING

W. Ellis Davies

The Assessment of breeder's material (W.E.D., B.F.T.)

White clover is usually grown with a companion grass and utilized by the animal *in situ* or cut for forage. The interaction of grass and clover must, therefore, have an important bearing on the ultimate yields. The situation is, however, complicated by the differential effect of the grazing animal on the constituents of the sward. For several years now work has been in progress to ascertain whether data from widely spaced plants in the breeding nursery could be correlated with data from swards. Because of shortage of seed, suitable plots were established by planting white clover seedlings 1 ft. apart each way and oversowing with a companion grass to introduce the competition factor. The effect of the grazing animal was obtained by pre-grazing sampling and folding sheep on the plots. Botanical and chemical analyses were made on the samples, and chemical analysis on comparable spaced plants.

The first growth in spring was grazed, the recovery growth was cut for silage, and subsequent cuts were grazed. It was eventually possible to correlate the results from the spaced plants with those from the grazed swards:

Correlation coefficients (r) of widely-spaced plants of white clover with those from broadcast plots

	Length of leaf	*Height of leaf*	*Yield of clover*
Expt. 1 Seeding year	0.969**	0.903**	0.675**
1st harvest year	0.879**	0.262	0.333
Expt. 2 ,, ,,	0.603**	0.345	–0.051
Expt. 3 ,, ,,	—	—	0.345

**P=0.01

The length of the leaf is highly correlated at each observation, while the height and yield show a significant correlation only in the seeding year. It is clear that the yield of white clover families as spaced plants is of little value in predicting the yield of the same white clover when grown in swards with a grass companion.

Cultural conditions for lucerne (W.E.D., B.F.T.)

Investigations with lucerne have been concerned with elucidating the cultural conditions best suited for the growth of the crop

to determine its potential value, and to test breeding material under optimal conditions. It has been shown that frequency and time of cutting are of paramount importance, but our earlier experiments did not give consistent results. Thus in one experiment three cuts per year seemed optimal, but in another this proved disastrous to the survival of lucerne. There was reason to suppose, however, that this was due to two unfavourable seasons in succession, (Davies *et al.* 1960). There was also a suggestion that when lucerne was sown in a mixture with grass, two cuts in the first year, followed subsequently by three cuts, would be beneficial to its survival. It was desired to test the reaction of other companion grasses and a new selection of late lucerne AF1 was available for testing. This variety was based on Grimm, Hungarian White Seal, and Provence families originally selected in 1938.

A new experiment was laid down in 1956 to provide further information on these points, (Report 1956–8, p. 27). Exceptionally wet conditions in the seeding year allowed very rapid establishment and growth of the companion and unsown grasses to the detriment of the lucerne, especially when quick-growing S.22 Italian ryegrass was sown, although the seed rate was 2 lb./acre. Nevertheless good yields were obtained and in the third harvest year the plot average was over 11,000 lb./acre dry matter.

Three cuts per annum gave a significantly higher yield (6.7%) than two cuts in the first harvest year, followed by three cuts in the two succeeding years. Meadow fescue S.215 was again the best companion grass, but its 5% higher yield than lucerne sown alone did not quite reach the significant level. The pattern of this superiority in yield was similar to that in previous experiments, in that the large difference in the first harvest year was gradually reduced to nil by the third harvest year. Italian ryegrass was included because results from France had shown that it was the only grass able to compete successfully with the vigorous early lucerne. The results from the mixture of lucerne with Italian ryegrass S.22, and lucerne with cocksfoot S.37 were 10% poorer than when lucerne was sown alone. This was because the Italian ryegrass S.22 had been very aggressive during establishment, and offered such strong competition that the lucerne was in a state of inanition, and many of the seedlings remained in the single tiller stage throughout the first winter. In the first harvest year the vigorous growth of Italian ryegrass depleted the nitrogen reserves, as the contribution from the legume at this time was very small. This allowed the lucerne to develop, and in subsequent years it did relatively better than

lucerne sown alone. Sown with cocksfoot, on the other hand, competition had more effect in the third year than in the first year.

The early type of lucerne, Du Puits, and its mixtures, gave a 20% higher yield than the late lucerne AF1. The latter being much more susceptible to grass competition than Du Puits gave a similar reaction to that obtained previously from Grimm.

From these studies it is concluded that three cuts per year is optimal for the present high-yielding varieties of lucerne. Cocksfoot and Italian ryegrass sown in mixtures with lucerne reduced the total yield. Meadow fescue S.215 remains the most suitable companion grass although it is not completely satisfactory. The productiveness of the meadow fescue in the lucerne/meadow fescue mixtures diminishes from year to year, so that eventually unsown grasses contribute more to the yield than the sown grass.

The persistency of broad red clover stands in relation to hard seeds (W.E.D.)

The belief is frequently held that present-day stocks of broad red clover are not as persistent as they used to be. One possible explanation is the presence of a high proportion of hard seeds in the rough-threshed samples. It used to be the practice on many farms to sow such seed, using a fairly high seed rate to ensure a sufficiently good establishment, as it was thought that the effects of age, weather, etc., on the hard seed coat would allow a certain percentage to germinate over a prolonged period and thus maintain a full stand. Modern seed-cleaning machinery as well as cleaning seed also scarifies it and reduces the percentage of hard seed to very small proportions. Germination will thus take place more or less simultaneously over a short period of time.

An experiment was set up to study the effect of different proportions of hard seed on the persistency of broad red clover. Seed was obtained of rough-threshed broad red clover with an initial germination of 31%, and this was treated and mixed as follows to give four different treatments, sown in six replicates :

Treatments	*Germination + hard seeds (per cent)*	*Seed rate (lb./ac.)*
Scarified	86 + 14	6
,, and unscarified	40 + 60	6
,, ,, ,,	40 + 60	12
Unscarified	31 + 69	18

Plant counts were made over three harvest years and it was found that the number per sq. ft. dropped steadily from 9.9 in March of the first harvest year to 0.5 in August of the third year. The plots sown with most hard seeds had slightly higher plant numbers throughout, but this was not reflected in greater yield, and no significant differences were observed in the three cuts taken up to June of the second harvest year. After this date the amount of broad red clover in the plots was so small as not to merit cutting for yield estimations. The plant counts were continued, and in March of the third harvest year half of each plot was harrowed, forked and rolled to encourage further germination of hard seeds. In the subsequent count an attempt was made to classify the plants into new seedlings and established plants, but although statistically different in the treatments, the number was too small to make a noticeable difference and the general trend continued.

These findings can best be explained by the results of Robinson (1960) *Agron. J.*, 52, 212–214, who used hard seed of Ladino white clover. He found that a high percentage germination was obtained after cold temperature pre-treatment followed by alternating high and low temperatures. The majority of the hard seeds would germinate in the spring of the first harvest year, with a small percentage in the second spring and practically none in the third.

Investigations on "wild lucerne" (A.M.E.)

Progress has been made in the identification and classification of the "wild lucerne" species introduced from U.S.S.R. With the exception of *Medicago platycarpa* the species under investigation belong to the tribe *Falcago* of the genus *Medicago*. Using the characters of flower colour and pod shape the species can be divided into the following groups:

Group	*Flowers*	*Pods*
I	Purple	Spiral
II	Yellow	Sickle-shape
III	„	Spiral
IV	Purple	Sickle-shape

In the samples studied there were many aberrant types, presumably caused by natural interspecific hybridization. This was particularly true of the samples of *M. gaetula* (4x), *M. falcata* (4x) and *M. glutinosa* (4x), where several plants showed blue or green flowers characteristic of hybrids.

Group	Species	Growth habit scale†	GLASSHOUSE DATA					FIELD DATA			
			Leaf size relative to M. sativa 4x =100	Internode No.		Tiller length (cm.)		Mean flowering time relative to M. sativa 4x (days)	Tiller No.	Yield relative to M. sativa 4x 1st cut=100	
				Mean	Range	Mean	Longest			1st cut	2nd cut
I	*M. sativa* (4x)	2.1	100	12.6	10–17	30.0	41.7	14/6/60	41.4	100	86
	Wild types										
	M. sativa (2x) (3 plants)	4.0	35.2	13.8	13–15	23.0	26.9	–11	—	—	—
	M. gaetula (4x)	2.6 (1–4)	59.9	12.4	11–16	25.1	33.0	—	—	—	—
	M. gaetula (2x)	3.6	42.4	—	—	—	—	–4	19.1	56	18
	M. caerulea (2x)	4.9	47.8	15.0	11–17	35.6	49.6	+2	25.4	115	38
II	*M. falcata* (4x)	3.2 (2–4)	69.2	13.6	12–16	31.7	42.8	–2	34.6	64	38
	M. quasifalcata (2x)	3.6	42.2	15.8	13–18	28.8	36.1	–4	20.3	37	16
III	*M. glutinosa* (4x)	2.3 (1–4)	84.4	11.4	9–15	31.8	37.6	–8	32.8	90	53
	M. dzawakhetica (2x)	4.0	38.6	—	—	—	—	—	—	—	—
IV	*M. hemicycla* (2x)	4.8	41.3	13.1	11–16	27.1	41.2	–16	27.7	80	32
	Other types										
	M. media	4.9	69.8	14.9	14–17	29.5	36.6	–2	40.2	78	47
	M. platycarpa	4.5	255.0	15.8	12–20	38.1	57.0	–16	—	—	—
	M. sativa (8x)	—	—	—	—	—	—	+4	24.8	62	38

†Growth habit scale: 1 = upright; 5 = prostrate

The table shows the grouping of the 13 samples under investigation, a summary of characters recorded in the glasshouse on 10 plants per species, and the performance of the species under spaced-plant conditions in the field.

In growth habit *M. sativa* (4x) was the most erect, while *M. caerulea* and the natural hybrid (*M. media*) were the most prostrate. The range in the three tetraploid species *M. gaetula*, *M. falcata* and *M. glutinosa* is further evidence of the great variety of types present in these samples. *M. glutinosa* had fewest internodes per flowering tiller while *M. quasifalcata* and *M. platycarpa* had the greatest number. The size of the middle leaflet of the third leaf from the top of the tiller was measured, and relative to *M. sativa* (4x) all the species of *Falcago* had smaller leaves, the diploid species having the smallest. Mean tiller length, and length of the longest tiller were variable characters.

Species in Groups II and III can be distinguished on the basis of ploidy. In Group I the tetraploid *M. gaetula* is distinguishable from *M. sativa* 4x because of its smaller and finer leaves. The three diploid species in Group I are somewhat difficult to distinguish by these characters and in the glasshouse they differ markedly only in tiller length. *M. sativa* (2x) was 11 days earlier than *M. sativa* (4x), while *M. gaetula* (2x) was 4 days earlier, and *M. caerulea* (2x) 2 days later in flowering. All the other species flowered earlier than *M. sativa* (4x) with the exception of the octoploid, which was latest of all. *M. sativa* (4x) and *M. glutinosa* have a significantly greater number of tillers than the other species which do not differ significantly from one another. *M. caerulea* at the first cut outyielded the other species, but was not significantly greater than *M. sativa* and *M. glutinosa*. The yield of all the species at the second cut was lower, but the wild species, particularly the diploids, were appreciably lower. This is characteristic of wild species which are slow to recover after cutting and have a long dormancy period.

Particularly valuable characteristics were noted in the field, namely, that the true yellow-flowering *glutinosa* plants had a sub-ground-level crown with only the tillers appearing above the soil. This is a character which would be desirable in a grazing variety of lucerne as it would avoid damage to the crown by the grazing animal. Leafiness and high leaf : stem in *M. caerulea* might well also be a valuable attribute. The winter greenness of the natural hybrid from Ayrshire (*M. media*) was very marked in this experiment. The following desirable attributes have also been ascribed to wild lucernes by other workers, notably Sinskaya, E.N. 1948. *Trud.*

Prikladnoi, Bot. Genet. Selekcii, Vol. 28 No. 1, 11–47 (Russian). *Pl. Breed. Abstr.* 1954, 24, (Abstr. No. 1175).

M. gaetula, M. caerulea	—	Drought resistant
M. hemicycla	—	Tolerant to high precipitation
M. hemicycla, M. falcata	—	Cold resistant
M. hemicycla, M. gaetula	—	Wilt resistant
M. caerulea	—	Stem nematode resistant

The diploids of these species hybridize fairly readily, as do the tetraploids, but only in two instances was seed obtained from a tetraploid × diploid cross, namely:

M. sativa (4x)	×	*M. caerulea* (2x)	3 seeds
M. sativa (4x)	×	*M. hemicycla* (2x)	13 seeds

The overall picture of the self- and cross-compatibilities of these species is :

Fertility relationships in Medicago

	Self-fertility	*M. sativa* 2x	*M. falcata* 2x	*M. hemicycla* 2x	*M. caerulea* 2x	*M. gaetula* 2x	*M. sativa* 4x	*M. falcata* 4x	*M. media* 4x	*M. glutinosa* 4x
Diploid (2x)										
M. sativa	1	5								
M. falcata	1	4	5							
M. hemicycla	1	3	2	5						
M. caerulea	1	3	2	3	5					
M. gaetula	0	3	3	4	4	5				
Tetraploid (4x)										
M. sativa	4	0	0	1	1	1	5			
M. falcata	3	0	0	0	0	0	4	5		
M. media	2	0	0	0	0	0	4	4	5	
M. glutinosa	4	0	0	0	0	0	4	3	3	5

Scale :
0 = Completely sterile
1 = Almost completely sterile
2 = Fertility very greatly reduced
3 = „ reduced
4 = „ somewhat reduced
5 = Complete fertility

It is evident that these wild species can be used as a source of germ-plasm for cultivated lucerne. When sufficient hybrid seed is available this new material will be tested on a field scale.

Genetical studies (A.M.E.)

The inheritance of flower colour and pod shape is being studied in the diploid species, and the following plants have been isolated :

	Flowers	*Pods*
M. hemicycla — (2 plants)	White	Sickle-shape
M. quasifalcata	Yellow	Sickle-shape
M. dzawakhetica	Yellow	Coiled
M. hemicycla	Purple	Sickle-shape
M. caerulea	Purple	Coiled

F_1 hybrids of these plants have been produced. Purple and yellow flowers are dominant to white, while purple crossed with yellow gives the intermediate blue-green colour. The F_1 plants show the intermediate pod shape characteristic ; coiled pods appear to be rather variable, depending largely on the number of seeds set in the pod.

Polyploid production in lucerne (A.M.E.)

Five chromosome races of *M. sativa* are available, and 4 of these were tested as spaced plants in the field.

	Yield relative to M. sativa (4x) *first cut* 1959=100		
	1959		1960
M. sativa	*First cut*	*Second cut*	*Third cut*
Chromosome race 32 (4x) (Du Puits)	100	150	65
„ „ 48 (6x)	79	94	36
„ „ 56 (7x)	63	87	32
„ „ 64 (8x)	51	81	22

The results show that with increasing ploidy the total yield under field conditions decreases, the octoploid ($2n = 8x = 64$) giving the lowest yield. The hexaploid ($2n = 6x = 48$) appeared to be the most promising ; it did not approach Du Puits in yield, but was leafy and free from leaf spot diseases.

Investigations into the symbiotic relationships between white clover and the nodule bacteria of the species *Rhizobium trifolii* (D.G.J.)

In outbreeding species the amount of genetic variation within a variety is bound to be quite large. With this in mind, the symbiotic patterns between S.100 Nomark White Clover and the many indigenous strains of *Rhizobium* that can cause its nodulation were investigated. The aim was to select suitable lines for incorporation into one improved variety based on symbiotic response, as well as to study other nodulation problems.

The investigation can be divided into two parts, the survey of the effectiveness of bacterial isolates from different localities, and the variation in host response within the variety S.100 Nomark when inoculated with only one effective strain of *Rhizobium*.

Bacterial Survey

There are innumerable rhizobial strains in the soils of Great Britain and the response they produce in symbiosis with any particular leguminous host shows a gradation from effectiveness to ineffectiveness. One can generalise, however, by saying that there are three main types of response, effective, intermediate and ineffective. The aim of this survey was to categorize each isolate into these groups, collect data on their induced responses in the host, and to select strains typical of their groups which were stable enough to use in future work.

The assessment of effectiveness of nitrogen fixation was based on visual comparisons and dry weights. The plants were compared with effectively-nodulated plants which were used as standards. All plants were grown in test t bes from surface-sterilized seed on nitrogen-free, sterile agar medium, and inoculated with the various nodule bacteria isolates, the standard plants being inoculated with a known effective strain.

The only ineffective strains were isolated from wild white clover plants from unimproved mountain land: these strains induced numerous small white nodules on the tester-plants which remained small and yellow and were obviously receiving no nitrogen from the nodules. Many effective isolates were recovered and these originated from a wide range of localities, altitudes and soil types. Between these two extremes there were isolates which gave varying degrees of response. From this work strains typical of the three main categories have been selected and these have been incorporated into further experimental work.

Host variation

Five hundred seeds of S.100 Nomark were surface sterilized and sown on agar slopes under sterile conditions in test tubes, and inoculated with the most effective isolate of *Rhizobium* from the bacterial survey. Inoculation took place two days after sowing and the criterion for assessing the day of nodulation was the time at which the first discernible nodule appeared as a rounded swelling of the root, as opposed to the swelling of a lateral root. Observations were made on each plant ranging from the delay in nodule formation after inoculation to the number and size of nodules per plant, and the harvest dry weight after 70 days. It was found that there was a large variation in all these factors. For example, the first plant nodulated four days after inoculation whilst the last nodulated 12 days later. The size, weight and number of nodules per plant conformed more or less to the expected normal curve of distribution.

The number of nodules per plant and the eventual harvest dry weight were not correlated. There was a negative correlation between earliness of nodule formation and harvest dry weight, the earliest nodulating plants having a greater harvest dry weight than the latest. There was a highly significant positive correlation between the weight of nodules per plant and the harvest dry weight. There was a large variation in harvest dry weight after inoculation with the one rhizobial strain. A few plants gave an ineffective response and subsequent low dry weight, but most were within the effective-response category. The whole population response could be represented by a positively skewed curve of distribution the peak of which represented the effective response.

These data suggest that there are several factors controlled by the host genotype which could be selected for, and selections have been made for nodule number, earliness and lateness of nodule formation, and effectiveness of nitrogen fixation. Crosses between and within selections have been made but the progeny data are not yet available.

CEREALS, BEANS AND *BRASSICAE* BREEDING

D. J. Griffiths

WINTER OATS

After an exceptionally dry summer and autumn in 1959 the winter oat breeding material was sown under ideal conditions early in October. Germination, however, was somewhat delayed and the braird uneven, although full stands were eventually attained. The relatively mild winter which followed was not very effective in differentiating between hardy and non-hardy segregates. The warm dry spring of 1960 provided good conditions for growth, and harvesting was carried out before the onset of the very wet weather. On the whole, yields were very satisfactory and the grain showed little sign of weathering.

Breeding for improved field characters (D.J.G., J.D.H., I.J.)

Although marked improvements have been achieved in winter oats in recent years through the release of several new varieties which are higher yielding and stiffer strawed than S.147, further improvements in grain quality are still required. During the season 1959–60 special attention was given to this and to selecting for high yield and satisfactory straw strength.

The early and advanced generation segregates of various hybrid combinations were critically studied for grain characteristics. Promising lines possessing grain of good size and quality, as well as resistance to mildew, were isolated from F_4 and F_5 progenies of the two crosses 5370 Cn 2/2/41 × (S.147–S.172) and 5370 Cn 11/51 × Pennant (S.227).

Forty-eight advanced generation segregates and 9 mutant lines derived from irradiated S.172 and S.147 were included in full-scale replicated yield trials, in which no less than 47 gave higher yields than the standard control varieties S.147 and Powys, thus indicating that the ceiling of yield in the winter oat crop is well above that of S.147. Additional confirmatory evidence of the superiority of these lines was also obtained from the small scale yield trials which were undertaken at Seale-Hayne Agricultural College, Devon, and at the Norfolk Agricultural Station, Sprowston, through the co-operation of the National Institute of Agricultural Botany. From the results of these and previous trials, two selections, namely, 5370 Cn 15/9/45

and 5370 Cn 18/2/41 were seed-increased for inclusion in national trials during 1961, and selection 5687/5/10/1 for inclusion in 1962.

Of the nine mutant lines from S.147 and S.172 included in the full scale trials none gave a significantly increased yield over the control S.147, although some proved to be earlier maturing and slightly shorter strawed. Two of the more promising S.172 mutant lines were tested over 3 levels of fertility and 2 spacing treatments, but under none of the treatments did the mutant forms exceed the parental variety in yielding ability.

Selections in trial at the N.I.A.B.

Favourable reports were received during the year on the performance of the three winter oat selections in official trials at the N.I.A.B., namely 5370 Cn 2/2/41, a fairly stiff-strawed, mildew-resistant variety of winter oats possessing good quality grain, and the two eelworm-resistant selections E2296 and E2297. All three have shown considerable promise and have consistently outyielded the control varieties S.147 and Powys in all trials over several seasons. Because of the slightly superior standing ability shown by E2297 over its closely-related sister selection E2296, it has been decided to withdraw the latter from further trials.

Response to fertilizer treatments (J.D.H.)

Ideally, segregates with a wide range of adaptation should be selected in the early breeding trials, so that the ultimate pure-line varieties are suited to the varying levels of fertility in which they will be grown. There is very little information available regarding the relative response of winter oat varieties and segregates to differential levels of manuring in different seasons. Consequently the results from yield trials involving 8 fairly stiff-strawed varieties, including some of the latest selections from the breeding nursery, are of interest. These were tested over 3 levels of nitrogen in the two very different seasons of 1959 and 1960. The yield of S.172 at low level of nitrogen in 1958/9 = 100. The results are shown on page 43.

From the results and analysis it is clear that varietal differences in both seasons were consistent over the 3 levels of nitrogen. In 1958/9 there was a tendency for the less stiff-strawed varieties to lodge at the highest level of nitrogen, leading to a smaller increase of yield than was expected, thus contributing to significant varieties/treatments interaction. In 1959/60 although there was a marked

response to nitrogen there was neither lodging nor a significant variety/treatment interaction.

Relative grain yields of winter oat selections

Varieties/	N_0		N_1		N_2		*Mean*
Selections	58/9	59/60	58/9	59/60	58/9	59/60	*yields*
S.172	100	100	167	162	174	171	146
Powys	100	115	161	160	185	202	154
V907	108	137	184	179	222	202	172
5743 Cn 26/4/7	116	143	191	182	203	225	177
E2297	110	133	197	183	209	224	176
5370 Cn 2/2/41	124	143	197	210	204	245	187
5367 Cn 15/2/7	107	129	188	205	205	224	176
5687 Cn 5/10/1	112	134	201	216	211	241	186

N_0 = No Nitro-Chalk
N_1 = 3 cwt./acre Nitro-Chalk
N_2 = 6 „ „

Standard Errors	1958/9	1959/60
Varieties/treatments	4.75	8.62
Varieties	2.74	5.07
Treatments	2.19	4.29

Analysis of variance

	1958/9		1959/60		*Combined analysis*	
Source	*Var. Ratio*	*d.f.*	*Var. Ratio*	*d.f.*	*Var. Ratio*	*d.f.*
Treatments	505.87***	(2+6)	107.56***	(2+6)	95.85***	(2+2)
Varieties	17.19***	(7+63)	13.99***	(7+63)	20.73***	(7+162)
Varieties/Treatments	2.70**		1.42	(n.s.)	1.48**	
Varieties/Years					2.27*	(7+14)

*P=0.05 **P=0.01 ***P=0.001

SPRING OATS

The spring oats breeding programme was affected to a considerable extent by the adverse weather conditions in the 1960 growing season. The very dry conditions in the spring and early summer influenced the growth of the material and this, together with the

unusually wet harvest, made selection for agronomic characteristics difficult. Plant development was also seriously affected by heavy attacks of frit-fly. The widespread occurrence of the insect throughout the season, however, provided excellent opportunities for obtaining additional information on varietal reactions.

Breeding for improved field performance for high fertility conditions (D.J.G. W.T.H.P., I.T.J.)

For several seasons attempts have been made to obtain really short-strawed segregates possessing an open-type panicle, in contrast to the short-strawed, dense panicle types such as Milford S.225. Direct crosses involving Milford and taller-strawed varieties with open-type panicles have yielded progenies revealing a close linkage between straw length and panicle type. This season, however, the desired combinations were isolated from the progenies of a cross between the two Station Selections 4757/6/2/19 and 4602/4/180 and will thus furnish valuable parental material for further crossing. Promising eelworm-resistant selections were also obtained from crosses involving Manod S.235, Milford S.225 and the eelworm-resistant winter selection E2295.

Breeding for upland conditions (D.J.G.)

Over the past season at the hill centre the breeding investigations with oats for upland conditions were confined to yield testing of a large group of white- and black-grained advanced generation segregates derived from the cross D2973 × 01747/10/7, several of which have shown evidence of superiority over Maldwyn S.221 and S.220 in yielding ability, grain quality and earliness of maturity. One of the white-grained selections, 5405/2/2/44, was included for the first time in the N.I.A.B./N.A.A.S./W.P.B.S. co-operative upland variety trials conducted in Wales, where it outyielded all varieties under test, including Sun II, Maldwyn and S.220. In view of the promise shown by some of the black-grained segregates derived from this cross it has now been decided to withdraw the unnamed variety D2548 from further trials. Favourable reports were again received of V2661 from the North of Scotland and other places where straw is required as well as good quality grain.

Frit fly observations (W.T.H.P.)

Frit fly, one of the most destructive pests of spring sown oats, affects the crop in the seedling and panicle stages. Unfortunately

none of the varieties hitherto investigated possesses adequate genetic resistance upon which a breeding programme can be confidently based, although when grown together in the same location certain forms appear to be less severely attacked than others.

In 1960, five varieties were selected for critical study, three of which have been claimed as resistant, Doerflers Weihenstephan, Hohenheimer V and von Lochow's Yellow, and two known to be susceptible, to determine whether varieties which exhibit a measure of resistance in the seedling stage manifest a similar reaction to infection of the panicle.

The varieties were sown during the first week in May, in plots laid down as duplicate 5 × 5 Latin squares. The plots comprised two drills of 100 plants each. All the plants from one row of each plot were dug up for examination 10–12 days after the first indication of frit attack was observed in the susceptible variety Milford, At maturity representative panicles were taken from the remaining drill to observe the degree of infestation in the grain. Data were obtained on the number of seedling plants totally fritted, plants with the main tiller destroyed, proportion of tillers affected, and larvae present in the plants.

As indicated in the figures the level of infestation was very high, and although the three varieties of German origin proved superior to Milford and Powys, none manifested an outstanding degree of resistance.

The effects of frit fly attack on five oat varieties

Variety	*Per cent fritted tillers*	*Mean No. of larvae per plant (seedlings)*	*Per cent fritted 1st and 2nd grains*
Doerflers Weihenstephan	54.6	1.76	4.5
Hohenheimer V	61.9	1.98	6.05
von Lochow's Yellow	62.8	2.02	4.8
Powys (S.226)	84.7	5.40	10.7
Milford (S.225)	84.7	6.06	8.7
Sig. diff. (P = 0.05)	±8.41	±0.886	±3.38

Doerflers Weihenstephan, Hohenheimer V and von Lochow's Yellow are erect low-tillering varieties which make rapid early growth and therefore pass through the susceptible stage more quickly than the slower developing varieties like Milford. Such an escape

mechanism, however, does not explain the superiority of these varieties over Milford in respect of panicle stage infection.

Oat mildew studies (D.J.G.)

Spraying experiments have been carried out during the last two seasons to determine the effects of mildew on the spring sown oat crop. Plots of Sun II sprayed to control the mildew, significantly outyielded the unsprayed control plots in both seasons, the differences being 3.83 cwt./acre (11%) in 1959, a season of moderate infection, and 6.09 cwt./acre (16%) in 1960, a season of high incidence of mildew. These estimates clearly indicate that the losses in yield of grain caused by mildew can be very considerable, and fully confirm the need for resistant varieties.

In the breeding nurseries segregates derived from crosses involving the 01747/10/7 and Cc4146 type resistance to mildew maintained their resistant reaction in the early part of the season, but later manifested symptoms of partial breakdown. Work is now in progress to determine whether this partial breakdown was due to environmental factors, or to the appearance of more virulent biotypes in the nursery.

Oat crown rust breeding investigations (D.J.G.)

Four different sources of crown rust resistance, namely, Bond, Victoria, Landhafer and Ascencao type resistances are now being utilized in crosses and backcrosses to obtain resistance to all the known races in Britain. During 1960 the F_3 generation progenies of the third backcross of Ascencao to Sun II and other varieties were screened for reaction to Race 96. Ascencao has been introduced recently into the breeding programme because of its resistance to all the races identified at Aberystwyth, including Race 274, which is pathogenic on Bond and Victoria.

Halo blight studies (W.T.H.P.)

The investigational work on halo blight, a bacterial seed-borne disease of oats, has now been completed. A suitable technique has been developed for its control through the treatment of the seed with streptomycin just prior to sowing. Inoculation tests undertaken on the progenies of crosses involving the resistant form Cc4146 and susceptible varieties, indicated that reaction to the disease is conditioned by a single genetic factor with susceptibility partially dominant to resistance in the F_1. Resistance was found to be

ndependent of mildew reaction and of the undesirable grain cha racters found in Cc4146.

Cytogenetic investigations (D.J.G., W.T.H.P.)

Studies were undertaken on the A_2 generation plants of two new synthetic hexaploids produced by colchicine treatment of triploid hybrids of *A. abyssinica* × S.75 and *A. abyssinica* × S.171. Cytological studies of meiosis revealed essentially the same pattern of pairing as that reported previously for the *A. barbata* — *A. hirtula* 6x amphiploids. The A_2 generation plants showed considerable variation in fertility, chromosome number and chromosome pairing, with the *A. abyssinica*—S.171 amphiploid progenies showing rather better fertility and pairing than the others.

Hybrids were obtained from crosses of amphiploids and the cultivated 42-chromosome forms, but these again proved almost completely sterile. Attempts to backcross to *A. sativa* using these hybrids as the female parent gave only four seeds from several hundred crosses attempted.

The F_2 and F_3 generations of the cross between a *cultivated base type* 6x amphiploid and *wild base* 6x amphiploid were studied for grain base segregation, and the results revealed an entirely different segregation of types from that obtained from crossing *A. fatua* (*shedding base type*) with *A. sativa* (*non-shedding solid base type*).

BARLEY

Breeding for resistance to mildew (J.D.H., I.T.J.)

Genotypes which are reputed to have disease resistance under various conditions have been screened in the field and glasshouse. Clear-cut resistance to mildew Race B9 (based on the German classification) has been established in a large number of the varieties tested. This resistance appears to be due to a single dominant gene. Varieties such as York (Cb 795), reputed to be resistant under Canadian conditions, have proved to be susceptible under glasshouse and field conditions, and the breakdown of resistance in varieties such as Union and Vada confirms that resistance to mildew is controlled by more than one gene.

The barley mildew resistance breeding programme is based largely on backcrossing genotypes carrying resistance to different races of mildew into common parents of wide adaptation, and of proven malting and agricultural value. Through the use of

extended daylength four backcross generations have been completed in 18 months, and in this way immunity to the present mildew race population is being introduced into Proctor and Rika. Although this resistance is due to a single dominant gene, an F_2 population of each backcross hybrid is tested to ensure that no recessive genes for resistance are being missed in the programme. When new races of the pathogen appear it is hoped to isolate resistance to these forms, and to introduce the genes into the same parents. The Proctor and Rika lines carrying resistance to the different races of this pathogen should prove invaluable as parents for future breeding work.

Breeding for improved field characters (J.D.H., I.T.J., I.J.)

Although the major part of the barley breeding programme is directed toward the isolation of high yielding varieties of barley of good malting quality, some effort is also being directed towards the development of high yielding varieties of feeding barley suitable for land where it is difficult to produce malting samples. In this connection selections from F_3 pooled populations containing segregates of crosses between Kenia and high protein naked barleys from Turkey and Yugoslavia, have been isolated to ascertain whether stiff-strawed, high protein lines can be extracted from such crosses. These will be seed increased for chemical analysis during the coming year.

The series of 6- and 2-rowed isogenic lines which were obtained from Dr. G. A. Wiebe, U.S. Department of Agriculture, have indicated that the 6-rowed genotype has a higher grain-yielding capacity than the 2-rowed form. Selections have now been taken from crosses of 6- and 2-rowed varieties which are adapted to British conditions, these include Prefect and Cb 740 (a 6-rowed type from Eire), Herta and Domen. The selections are being tested in an early generation trial in order to ascertain whether stiff-strawed 6-rowed genotypes could give rise to higher yielding varieties.

Diallel crosses (J.D.H.)

The yielding ability of various segregates from diallel crosses of the 2-rowed parents from the isogenic series, based on the performance of F_1 and F_2 spaced plants, and F_2 and F_3 drills, was investigated. There was a fairly close correlation between the performance of the parental varieties when sown as spaced plants and when grown under competition in drills.

Plants were grown in the field of F_1 hybrids of another diallel cross (C.399b) which involved 10 parental varieties, including some

of the earlier types grown in this country, as well as some of the more successful forms derived from them. Data were recorded on date of heading, height at maturity, number of grains per head, ear conformation, weight of 1,000 grains and yield per plant. This series of parents showed a low degree of correlation between the expression of certain important characters as spaced plants, and when grown under competition. This apparent lack of correlation in parental behaviour, therefore, must of necessity limit the validity of any conclusions which may be drawn from the genetic analysis of the results of F_1 hybrids grown as spaced plants, regarding the potential value of any particular cross to give outstanding segregates when grown under competition. It is intended, therefore, to grow the F_2 plants in drills for seed increase in order that sufficient seed may be available to sow replicated yield trials of bulk populations derived from each cross for subsequent analysis.

SPRING WHEAT

Breeding for improved field characters (D.J.G., I.J.)

Breeding work with spring wheat in 1960 was confined to the study of the F_3 progenies of crosses involving Atson, Koga II, Svenno, Peko, Miana and Station Sel. No. 2 as parents. These were screened for early maturity, straw stiffness and disease reaction under field conditions, and the most promising were harvested and threshed for grain examination in the laboratory. After a further reduction in number on the basis of grain appearance they will be grown in small scale yield trials in 1961, with Koga II as the standard variety. Of the crosses investigated, Koga II $\times$ Svenno, and Koga II $\times$ Station Sel. No. 2 yielded the highest proportion of desirable segregates worthy of extended study.

FORAGE RYE

Breeding for forage production (J.D.H.)

Studies were undertaken on the progenies from open-pollinated head selections originally derived from populations of winter rye from Central Europe and from the Giant English Ryes. These were screened for improved tillering capacity, ability to make growth at low temperatures, and for their response to early spring dressings of a nitrogenous fertilizer. Four populations from the first cycle of

selection were included in tests, and head selections from these populations are being subjected to a further cycle of selection.

MAIZE FOR SILAGE

Preliminary agronomic observations (D.J.G., T.D.J.)

With the recent introduction of quick-maturing maize hybrids it has become possible to grow good crops of this species for cutting green and making into silage in areas where early sowings can be undertaken without risk of frost. Over the last few years considerable interest has been shown by farmers in this crop now that the problems of mechanical harvesting have been largely overcome.

During the year under review some of these hybrids of American and Dutch origin were grown for observation, and also to obtain some preliminary information on their relative yielding capacity. The plots were sampled on 5 and 20 September, and 5 October, and it was noted that a rapid increase of dry matter yields occurred only in those hybrids which approached maturity within this period. Cob development was accompanied by an increase in total fresh yield and a simultaneous rise in dry matter percentage, both changes being in marked contrast to a very slow increase in fresh yield and consistently low percentage of dry matter in the late maturing lines.

FIELD BEANS

Work with field beans was concerned in the main with the problem of self-fertility in relation to possible methods of improving yields and eliminating marked seasonal fluctuations in the crop.

Inbreeding studies (H.T.)

The response to four seasons of selection for self-fertility in British populations of spring beans has been slow and so far has not produced any outstanding lines. Two fairly promising lines with distinctly improved seed-setting capabilities were isolated from third generation inbred plants of Tick beans grown under bee-proof conditions. These particular lines, the S_4 generation progenies of a single plant originally selected in 1956, have consistently shown superior self-fertility through each generation of inbreeding.

In addition to the selfing studies undertaken on British populations of spring beans, varieties from foreign sources have also been

screened for their ability to set seed under bee-proof conditions, and of these, certain lines of Mediterranean and Persian origin have shown promise. As expected, these types are poorly adapted to British conditions, and therefore they have been crossed with various agronomically-adapted selections for the purpose of selecting vigorous, self-fertile lines from the segregating populations. The F_2 and F_3 progenies of these crosses will be grown in 1961.

Production of synthetic varieties (H.T.)

Synthetic varieties based on combinations comprising from 2 to 8 distinctive lines selected on the basis of their performance in polycross and topcross progeny tests over the past season, were included in replicated yield trials to determine the best line combinations. The synthetics were set up in 1959 by mixing equal proportions of the components and growing them in isolation plots for interpollination, and the grain so produced was used in the 1960 replicated trials.

Although some of these synthetics showed slight superiority over the control variety Tick none of the combinations gave a significantly increased yield. In such tests it must be realized that the full manifestation of hybrid vigour has not been expressed, since only approximately 30% intercrossing occurs in the crop. In order to attain the full expression of hybrid vigour greatly increased hybridity is required, and this can only be achieved through the introduction of genetic male sterility into the lines, or through the induction of male sterility by means of male gametocides.

KALES

The dry growing season of 1959 was not generally conducive to high yields, except on deep, loamy, soils with a normally high water table, under which conditions very good growth was made. The winter was not sufficiently severe for good assessment of winter hardiness. The spring of 1960 was again very dry, and, apart from some insect damage, seed yields from breeding material were good.

Intervarietal hybrids (T.D.J.)

Hybrids between a wide range of *B. oleracea* varieties have been produced including ' Canson ' thousand-headed kale, with marrow-stem kale and kohlrabi for the production of more winter hardy and

leafy marrow-stem types, and short thousand-headed kale with edible stems. F_1 populations involving different plants of the same varieties as the parents were found to differ widely in height, leafiness and stem thickness, thus emphasizing the need to use a wide range of parent plants as a basis for subsequent selection from hybrid material.

Inbreeding studies (T.D.J.)

First generation inbred lines of marrow-stem and Canson kales grown in 1959 showed a very great range of morphological types with a high degree of within-line uniformity. Plants were selected from these lines for use in 1960 in diallel crosses to investigate the genetic basis of a number of important agronomic characters. Preliminary examination of the 7 × 7 marrow-stem diallel experiment indicated that plant height is determined by a number of genes with relatively small effects, but showing some evidence of over-dominance.

RAPE

In contrast to the hot dry summer of 1959, the second half of 1960 was very wet and well suited to the growing of rape. The abnormally high rainfall, however, caused severe leaching from the soil of soluble nitrogenous compounds, and as a result nitrogen starvation occurred frequently, especially on the thin hill soils.

Clubroot-resistant varieties (T.D.J.)

Progress with the production of clubroot-resistant varieties of giant rape has continued. In 1960, 42 lines in the F_3 generation were tested for yield on clean land at 700′ altitude. Variations between lines were not significant, although the mean values of the groups of lines with the same non-resistant parents were slightly higher than their respective non-resistant parent varieties of giant rape.

GRASSLAND AGRONOMY

Ll. Iorwerth Jones

Assessment of Perennial Ryegrass (D.G.M., R.J.K.W.)

Twenty-four varieties of perennial ryegrass were sown with S.100 white clover in April 1957, and their production of herbage during the following years recorded. These varieties were from Belgium, Denmark, France, Germany, Ireland, Netherlands, Sweden and the United Kingdom, and apart from our own variety Ba 6293 they were all included in trials in O.E.E.C. Project 210. The swards were rotationally grazed by sheep and one silage cut was taken at the peak of growth. The varieties were divided into two groups according to the date of ear emergence recorded at Versailles in 1956, and sown on adjacent areas to facilitate ease of management. In the light of subsequent evidence Viktoria, Glasnevin and Sildig Øtofte II should have been included in the early-flowering group, and Hooitype C.B. in the late-flowering group. Fertilizer dressings consisted of 3 cwt./acre compound fertilizer (12 : 12 : 18) in the autumn and 3 cwt./acre Nitro-Chalk each spring.

The herbage production of the varieties within each group at the different periods of the year is shown on the next page.

Early-flowering group. In the seeding year all varieties became well established. There was little to distinguish most of the varieties in terms of production, but Odenwalder, Steinacher and Irish were below average in total yield, and Irish showed the lowest ryegrass content of all varieties.

Differences in spring production were evident in the first harvest year. S.24 and Devon Eaver surpassed all other varieties in total yield, followed by Primevere and Melle Hay. During subsequent years Devon Eaver also gave high early spring yields, but proved to be much less persistent than S.24.

There were indications that varieties from continental sources were capable of better summer production than those from more maritime centres.

Some variation in autumn production was evident in the first harvest year; the trends became more marked subsequently. At this season S.24 was consistently high yielding, followed closely by Hooitype C.B., Vroeghooitype Barenza, and Melle Hay, but Irish, Devon Eaver, Odenwalder and Steinacher were relatively poor.

Early-flowering varieties in order of ear emergence

A = Best

Varieties	*Seeding year*	*Spring*	*Late Spring & Summer*	*Autumn*	*Total*
Devon Eaver	B	**A**	C	C	B
Irish	C	B	C	C	C
Primevere	**A**	B	C	B	C
S.24	**A**	**A**	C	**A**	**A**
Delta	B	B	B	C	B
Steinacher	C	B	B	C	C
Odenwalder	C	C	**A**	B	C
Vroeghooitype Barenza	**A**	C	B	**A**	C
Melle Hay	B	B	**A**	**A**	**A**
Hooitype C.B.	**A**	C	C	**A**	C
Per cent increase of Group **A** over Group C	24%	25%	13%	31%	12%

Intermediate and late-flowering varieties in order of ear emergence

Varieties	*Seeding year*	*Spring*	*Late Spring & Summer*	*Autumn*	*Total*
Viktoria	D	D	D	D	D
Glasnevin	D	**A**	D	B	C
Sildig Øtofte II	C	**A**	C	C	B
Ba 6293	**A**	**A**	B	**A**	**A**
Hunsballe II	C	B	C	D	C
Kent	C	C	B	C	C
S.101	C	**A**	**A**	B	**A**
Hooitype Barenza	C	B	B	D	C
S.23	C	D	**A**	**A**	B
Trianon	C	C	**A**	B	B
Mommersteeg's Hooitype	C	B	B	D	C
Sceempter Weidetype	B	C	**A**	B	B
Weidetype Barenza	C	**A**	B	B	B
Melle Pasture	C	C	C	B	C
Per cent increase of Group **A** over Group D	63%	23%	19%	25%	25%

In general, all the varieties included in the early-flowering group showed better persistency than Devon Eaver and Irish, both of which were considerably thinned out by the third harvest year.

Late-flowering group. With the exception of Ba 6293, there was little to distinguish the varieties in the vigour of their establishment or production during the seeding year. The yield of herbage was at a fairly high level in the spring in all varieties; Ba 6293, Sildig Øtofte II, Glasnevin leafy, S.101 and Weidetype Barenza gave most, S.23 and Viktoria least.

Summer production figures showed little deviation from the average, but in the autumn of each year differences in the behaviour of a number of varieties became obvious. S.23 and Ba 6293 were relatively good at this season, and Viktoria, Mommersteeg's Hooitype and Hooitype Barenza relatively poor.

Considerable differences in persistency have been shown in this trial, Viktoria was the least persistent under the management applied, and S.23 at the other extreme was outstandingly persistent.

Observations on S.170 tall fescue (LL.I.J., A.H.C.)

The production of grass in early spring not only reduces the need for herbage conservation, but also provides valuable green food for the animals after indoor winter feeding. Certain grasses are more able to provide out-of-season herbage than others, but in general the better species are normally short-lived. Tall fescue is one of the exceptions ; it is a perennial, and produces out-of-season growth. The majority of varieties on the market are rather coarse, stemmy, and unable to persist under grazing conditions. S.170 tall fescue, however, is leafy, persistent and is without the normal coarseness associated with this species. The potentialities of S.170 tall fescue have been under study at the Welsh Plant Breeding Station. Some of the findings are reported here.

Establishment and development of the sward. In common with other varieties of tall fescue, seedlings of S.170 are slow to develop, and in order to produce a satisfactory sward fairly high seed rates must be employed. A trial to compare the production of herbage from three sowing rates 10, 20, and 30 lb. of viable seed per acre, shows the superiority of the heavier seed rate for the first twelve months, whereas the inferior production from the lighter seed rate was evident even in the second harvest year. This is shown by the

relative yields of S.170 herbage for two harvest years (10 lb./acre seeding = 100) for each year :

	Seed rate (lb./acre)		
	10	20	30
First harvest year (June)	100	175	250
Second harvest year (March)	100	139	138

Owing to its slow development S.170 is markedly suppressed by other grass species ; this was far more evident when the seeds were broadcast than when sown in alternate drills 8″ apart. In an investigation of its ability to thrive with other species it was observed that the ryegrasses, and in particular S.22 Italian ryegrass, suppressed S.170 markedly during the first 18 months. In the following two years, however, the tall fescue made a remarkable recovery under both a rotational system of grazing and under hay with aftermath grazing. The percentage contribution of S.170 tall fescue to the total herbage is indicated as follows :

Mixtures	*Rotational grazing* *Harvest year*			*Hay and aftermath grazing* *Harvest year*		
	1st	*2nd*	*3rd*	*1st*	*2nd*	*3rd*
S.170 + S.100	59	88	82	28	70	68
„ + „ + S.23	25	26	44	8	25	38
„ + „ + S.24	11	47	68	5	30	40
„ + „ + S.22	1	6	44	1	19	36

In another investigation where the herbage was subjected to a system of cutting for conservation, the yield of S.170 tall fescue increased, while that of S.22 Italian ryegrass decreased from the first to the third harvest year. This was far more pronounced when both were included in the same sward than when grown separately. It was evident that S.170 tall fescue was severely suppressed by the S.22 Italian ryegrass in the mixed sward in the first harvest year, but by the third year it was the Italian ryegrass which had been almost completely suppressed. This is illustrated by the figures for the yield of the tall fescue and Italian ryegrass components of the sward, in 100 lb./acre :

Sward		*Harvest year*	
		1st	*3rd*
S.170 + S.100	Yield of S.170	57	81
S.22 + S.100	„ „ S.22	83	58
S.22 + S.170 + S.100	Yield of S.170	23	60
	Yield of S.22	52	7

Thus, provided defoliation is not too frequent S.170 tall fescue increases its contribution to the herbage in successive years, despite competition from aggressive species such as Italian and perennial ryegrass. Under regular heavy grazing by sheep on the hills, including very intensive grazing in April and May, the S.170 failed to make any material contribution to the herbage at any time.

Early spring growth. The most valuable character of S.170 tall fescue is its ability to produce early spring growth. In the first harvest year its early growth is often disappointing when sown late in the previous season, as is illustrated by the figures :

Date of sowing	*Relative yield of tall fescue in the following spring*
August 1954	32 to 100 for S.24
July 1952	51 to 100 for S.22
April 1958 and 1959	107 to 100 for S.24

Once S.170 was fully established its production was equal to, or better than, Italian ryegrass, depending on the damage suffered by the Italian following spells of hard frost. The spring growth of S.170 was always earlier than that of S.24, the earliest perennial ryegrass. By the beginning of May in the second, third and fourth harvest years the S.170 tall fescue provided an average of 33 more cattle-grazing days per acre than S.24.

In comparison with Alta tall fescue, S.170 was superior, particularly in spring herbage production. Following a very cold winter in 1954 (second harvest year) S.170 provided 60% more early spring growth than Alta. The data from another trial grazed by sheep on a rotational basis for five years show that whilst the total annual yield of herbage was almost identical for the two varieties, the yields of the tall fescue component and of the early spring herbage were markedly superior in swards based on S.170. This is illustrated by the relative figures (Alta = 100):

	Swards based on	
Annual yield	*Alta*	*S.170*
Total yield of all herbage	100	101
Yield of tall fescue component	100	116
Yield of unsown grasses	100	55
Spring yield		
Total yield of all herbage	100	121
Yield of tall fescue component	100	134

Animal production. Some reports, particularly from overseas, indicate that animals do not thrive on swards in which tall fescue is a component. In 1954 a trial was set up to compare animal production in terms of live weight gains from swards based on S.170 tall fescue and on S.24 perennial ryegrass, S.100 white clover being a constituent of both. The following figures show the annual performance of these two swards :

	Swards based on	
	Perennial ryegrass	*Tall fescue*
	S.24	*S.170*
Gain in live-weight of cattle (lb./acre/annum)	572 lb.	602 lb.
Number of cattle grazing days (per acre/annum)	362 days	388 days
Gain in live weight (lb./beast/day)	1.58 lb.	1.55 lb.

These figures indicate a similar live weight production per beast per grazing day, but owing to a slight increase in the number of grazing days provided by the S.170 sward, the live weight gain per acre was about 5% higher. During this trial the animals suffered no ill-effects when grazing the S.170 sward, although the herbage consumed over four years on an average consisted of 65% tall fescue, 30% white clover and 5% other species.

Palatability and persistency. Animals which had access to various swards did not graze the S.170 sward to the same extent as the others, particularly during late spring and early summer. However, no difficulty was experienced in obtaining full utilization of the S.170 sward provided stock had access to it when in the young leafy stage, and not to other swards at the same time. In these circumstances

the performance of the animals was equal to when they were grazing S.24 perennial ryegrass. It was observed that after a grazing at the end of March or early in April, and another at the end of April or early in May the regrowth tended to become coarse and unpalatable. Mowing the herbage at this stage not only provided hay or silage for winter feeding, but also reduced head formation and coarseness in the herbage, and improved the palatability of subsequent grazings.

Unlike most early-growing grasses, S.170 tall fescue combines early spring growth with persistency. Under rotational grazing for five years S.170 maintained its vigorous growth throughout, and even in the fifth year it contributed 84% by weight of the total herbage. Regular grazing by sheep, particularly the hard grazing experienced in March and April on the hills, retarded its development. Under lowland conditions resting the sward for six weeks between successive grazings, compared with three weeks, increased the density of the sward in the seeding year by 53%, and gave a better persistency in the following years.

S.170 tall fescue is winter-hardy and suffers little damage in severe cold winters. Following such periods its early spring production far exceeds that of the Italian ryegrass or short-rotation ryegrass. In addition, during the 1955 dry season it withstood drought much better than any of the other 28 varieties representing 15 species which were included in mixtures in the same field. Undoubtedly resistance to cold and to drought adds to the persistency of the variety.

Sward management : A critical growth stage in silage-making (I.D.)

Broadly speaking, when a sward is allowed to make unhindered growth during spring three developmental stages occur. The first is in early spring, when all tillers are devoid of stems. The second occurs when for a period of 3 to 6 weeks the proportion of tillers which remain in an entirely leafy condition steadily decreases, and growth begins to assume the erect habit associated with the early phases of stem formation. At this time there are :

(a) tillers in which stems are actually developing
(b) ,, ,, ,, ,, ,, about to develop
(c) ,, which are not immediately capable of stem formation.

At the commencement of this period (b) and (c) predominate ;

towards its close (a) and (c) are mainly in evidence, or (a) only (as in timothy).

The third stage occurs when (b) is no longer found. The growth now comprises stem tillers in which the stem apices have reached the level of defoliation, together with tillers which are devoid of stems (except in timothy). Amongst the latter are tillers in which stem formation is suppressed by the presence of the earlier-formed stems. This is especially true of perennial ryegrass.

The effects of defoliation. When the third stage is attained cutting involves the death of all stem tillers. Their dominating influence thus removed, reproductive differentiation begins amongst the remaining tillers, but the growth is nevertheless predominantly leafy. Heads do not begin to appear for 4 or 5 weeks. In contrast, cutting at the second stage, especially towards the end of the period, is followed by very rapid stem development with heads emerging only a fortnight or so after cutting (Ann. Rep. 1959 pp. 104–109).

The third stage is thus critical in herbage growth. In perennial ryegrass it coincides roughly with the time when heads first begin to emerge, although in an early season it may be attained in early-flowering varieties a week before head emergence. In timothy, on the other hand, it occurs 3 or 4 weeks before head emergence in early-flowering varieties such as American and Bd 2308, whilst in S.48 and S.51 the interval is 2–3 weeks. In this species, therefore, recognition of the stage depends on observing when stems have formed in all tillers and the shortest of them has attained the cutting level.

The following table illustrates some of these considerations, and indicates the effects of a pre-cut.

S.51 timothy : Density of tillers (per sq. ft.) making regrowth after cutting

	Plot series				
	1	2	3	4	5
Date of cutting	12/5	27/5	9/6	19/6	7/7
Treatment A — no pre-cut	145	92	12	2	4
Treatment B — following a pre-cut taken 4½ weeks earlier	160	144	71	75	173

Note : In 1958, the year in question, the second stage began early in May, and the third prior to 9th June.

The greater numbers of recovering tillers under Treatment B in Series 1 and 2 are due to the delaying influence of the pre-cuts on stem formation.

Under Treatment A, the negligible recovery following cuts later than 9 June indicates the almost complete dominance of the primary stem tillers.

Following the removal of an increasing proportion of stems by the pre-cuts on Plot Series 3–5 a new generation of tillers developed before the remaining stem tillers were removed in the subsequent cut. Stem formation in the new tillers did not begin until at least 3 or 4 weeks after cutting.

When herbage is put-up early for silage and allowed unhindered development a well-defined critical stage occurs. A single earlier defoliation at the first stage may not affect this, except by delaying it. Defoliation at the second reduces the suppressing influence of the first-formed stem tillers, resulting in a less well-defined critical stage.

Under frequent grazing, observations indicate that apical dominance is far less pronounced. There are no well-defined growth stages, stems are formed more or less continuously in the period of reproductive development, and heads may emerge during a rest period of as little as three weeks.

Root studies (A.T.)

Using conventional techniques it is not possible to measure the size of the root and shoot systems of a plant without separating them, and thus destroying the plant at the first measurement. Therefore, although this enables a calculation to be made of the relative growth of the roots and shoots within a population it is unsuitable for measuring the root/shoot growth of an individual plant over a period.

During the past year a technique has been developed to enable the volume of the root and shoot systems of plants growing in nutrient solution to be measured without disturbing the plant's growth, by using a method based on water displacement. By measuring the volume at intervals it has been possible to calculate the constant k† in the allometric formula for individual plants when the growth rates are calculated on the basis of increase in volume.

In this manner five varieties of *Lolium perenne* were compared. There was considerable variation between the means of the varieties and even more within the varieties.

$$\dagger k = \frac{(\text{log. growth rate of the root})}{(\text{,, ,, ,, ,, ,, shoot})}$$

Values of k for plants of five varieties of Lolium perenne

	Minimum	*Maximum*	*Mean*
Irish	0.48 ± 0.07	0.86 ± 0.07	0.69
Hunsballe	0.63 ± 0.08	0.86 ± 0.09	0.77
S.23	0.61 ± 0.11	1.03 ± 0.02	0.80
S.24	0.57 ± 0.11	0.99 ± 0.08	0.82
Melle Pasture	0.76 ± 0.07	1.01 ± 0.04	0.85

Within one variety it has been possible to select some plants with high, and others with low, values of k for use in genetic and physiological investigations.

This technique was used to compare varieties of *Lolium perenne* when allowed to grow undisturbed, and also to measure their reaction to defoliation. After undisturbed growth for eight weeks the plants were defoliated 5 times at weekly intervals, leaving 2 cm. of the leaf bases and stems at each defoliation. A summary of the results is as follows :

Comparison of five varieties of Lolium perenne *marked in order of magnitude of the measurements*: (1 = *highest value*, 5 = *lowest value*)

	Irish	*S.23*	*Hunsballe*	*S.24*	*Melle Pasture*
Volume of shoot	5	3	2	1	4
,, ,, root	5	4	2	1	3
Percentage of the plant's volume in the roots	4	5	3	2	1
Value of k	5	3	4	2	1
Volume of shoot regrowth between 2–3 as a percentage of size	1	2	3	4	5
Plants with roots increasing in volume after first cut	1	3	2	5	4
Plant survival after five cuts	1	1	3	3	5

In nearly every instance the varieties can be ranked in the order Irish, S.23, Hunsballe, S.24, Melle Pasture, with relatively minor variations.

When the shoot growth made between the first and second cuts is expressed as a percentage of the size of the plant (shoot plus root) before the first cut, the differences between the varieties were small, but they were much greater in the regrowth after the second cut. The roots of some plants continued to grow after the first defoliation, while in others their volume started to decrease immediately, but the root volume of all plants decreased after the second defoliation. The number of plants whose roots continued to grow until the second defoliation appeared to be a varietal characteristic. For example, the roots of almost all plants of Irish ryegrass continued growing, whereas in perennial ryegrass S.24 very few plants made any further root growth after the first defoliation. The difference between the number of plants of each variety which survived five defoliations was small, but nevertheless the trends were the same as in the other measurements.

Varietal differences in size, proportion of the plant's growth in the roots, and the growth of both roots and shoots under a regime of weekly defoliation varied in the same manner, the small plants producing a relatively greater amount of shoot growth under the cutting treatment.

When all the plants in the experiment were regarded as a single population, their distribution between varieties being ignored, it was found that the amount of shoot growth between the first and second cuts depended very largely on the size of the plant before defoliation and the volume of the shoot left after the first cut. The relationship can be expressed by the following equation :

$$x_1 = 5.4 + 0.33x_2 - 0.50x_3$$

when x_1 represents the volume of regrowth, x_2 the size of the plant and x_3 the volume of shoot left after the first cut. Both regression coefficients are significant at the $P = 0.001$ level. Within the limits of this experiment the amount of regrowth varied with the size of the plant, but inversely with the size of the remaining shoot, i.e. the greater the amount of shoot left, the smaller the amount of regrowth. This latter result was somewhat unexpected. As the shoots were all cut the same distance from the base it suggests that plants with thin shoot bases produced more regrowth than did those with thick bases.

SEED MULTIPLICATION

Gwilym Evans

PRODUCTION AND DISTRIBUTION OF FOUNDATION SEED (H.M.R.)

In order to maintain adequate supplies of Foundation Seed of the herbage varieties 31 acres were sown during the year, and 24 crops (100 acres) were harvested. The reduction in the area sown from 80 acres in the previous year to 31 in the year under review was due to the favourable clover harvest in 1959, which enabled good reserves of red clover to be built up in the seed bank. This temporarily dispensed with the need to sow further acreages of the red clover varieties. The bulk of the established S.100 in the seed bank has been transferred to the National Institute of Agricultural Botany, Cambridge, for use as Stock Seed. Further reserves of seed of white clover varieties S.184 and S.100 Nomark are being built up.

Foundation Seed of grasses and clovers was distributed during 1959/60 to farmers for sowing 783 acres (804 acres in 1958/59) for the production of Stock Seed on contract with the N.I.A.B. In addition, 60 cwt. of S.22 Italian ryegrass and 6 cwt. of S.24 perennial ryegrass were allocated to the Ministry of Agriculture, Northern Ireland, for further multiplication under their official scheme.

A total of 110 tons (158 lots) of oat varieties bred at the Station was distributed in 1959/60 to merchants and Seed Growers' Associations operating the approved Cereal Seed Crop Inspection Schemes. Included in the distribution this year was the new spring oat Manod S.235, bred for resistance to mildew, rust and eelworm. An acreage of the new eelworm-resistant winter oat Pennant S.227 was sown on the Station's seed farm in the autumn of 1959 with a view to releasing it to the trade in the autumn of 1960.

RESULTS OF EXPERIMENTS

Seed productivity of ryegrass (H.M.R.)

Data obtained from demonstration plots of 14 varieties of perennial ryegrass, grouped according to date of ear emergence into early (May 5th) and late (May 31st), indicate that factors other than number and size of seed heads can affect the yield of seed. The late

emerging varieties gave higher mean figures for number and length of seed heads, but a much lower weight of 1000 seeds and less seed per acre than the early types. The early S.24 perennial ryegrass and the late S.23 gave yields which resembled the mean of their groups.

The important point brought out in the data is that when seed yields of different varieties are considered, only varieties within a group should be compared because of the immense effect the weight per 1000 seeds can have on the overall yield per acre.

The influence of time of sowing on behaviour of meadow fescue (J.L.)

Meadow fescue Aberystwyth S.53, S.215 and an American variety were sown in boxes at monthly intervals from March to August 1959. The seedlings were planted in the field ten weeks after sowing.

Seeding year. By the first autumn considerable differences in numbers of vegetative tillers were apparent. The bred varieties were much more robust, and counts made in October from March sowing gave the following figures :

	Mean tiller No./plant
S.53	137
S.215	144
American	82

Plants from sowings in March and April had developed inflorescences, but only rarely had they done so from the later sowings. The data show that a very high proportion of plants of the American variety came into head in the seeding year.

	Inflorescence production in meadow fescue in the seeding year : Seed sown in	
	March	*April*
Per cent plants heading :		
S.53	26.5	24.6
S.215	19.0	14.6
American	93.6	91.0
Inflorescences per plant :		
S.53	6	4
S.215	9	6
American	18	11

First harvest year

The precocious heading of the American variety in the seeding year may have reduced the fertile tiller numbers of the first harvest year, as can be seen from the following figures :

Relative fertile tiller numbers (American = 100)
sown in

	March	*April*	*May*	*June*	*July*	*August*
American	100(100)	100(101)	100(65)	100(40)	100(39)	100(26)
S.215	157(100)	160(103)	127(52)	114(29)	126(32)	117(19)
S.53	154(100)	156(102)	126(53)	127(33)	123(31)	137(23)

The relative figures in brackets=March sowing at 100, and show that fertile tiller production from the March and April sowings was almost double that from the May sowing, and four times as much as from the August sowing.

The effect of density on seed production (G.E.)

Red clover. At an original density of five plants per 8″ pot early-flowering red clover gave 66% of the number of flower heads produced by a late-flowering type. When 100 had been planted *per pot* the early variety produced only 19% of the number in the late type. High density, therefore, had a more severe effect on the early variety under such restricted conditions. The late variety gave 22% barren plants and the early variety 65%.

Grasses. Tall fescue S.170 failed to produced inflorescences when planted in boxes at $\frac{1}{2}'' \times \frac{1}{2}''$ spacing, whereas in S.24 perennial ryegrass the number of heads at $\frac{1}{2}'' \times \frac{1}{2}''$ was 40% of the number from $2'' \times 2''$ spacing.

At a density of 100 plants per 8″ pot, a pasture type cocksfoot and two varieties of meadow fescue failed to produce any inflorescences ; there was, however, an occasional head in Danish commercial cocksfoot. A diploid timothy at this density gave 40% of the number in the 5-plant density, and a hexaploid hay type timothy had 83% of the number in the sparsely-planted pots.

The evidence shows that the reaction to density in terms of inflorescence numbers may vary widely among genera, species, and even varieties within species.

Seed productivity in meadow fescue S.53. (J.L.)

An experiment in 1960 using clonal material from four plants of

S.53 confirmed the result from a trial in 1959. Nitro-Chalk at 6 cwt./acre applied in April gave an increased seed yield of 266 lb./acre over control (458 lb./acre) compared with an increase of 179 lb./acre when applied one month later.

The yield per unit area of plants spaced 9″ × 6″ was only 85% of those spaced 6″ × 6″, although the plants at the wider spacings gave considerably more fertile tillers and the yield per plant was much higher:

Mean seed yield and mean fertile tillers

		Nitro-Chalk 6 cwt./acre applied		*Spacing*	
	Control	1/4/60	30/4/60	6″×6″	9″×6″
Seed yield/plant (gm.)	1.49	2.31	2.01	1.69	2.18
Seed yield per 6″ × 6″	1.19	1.88	1.65	1.69	1.45
No. fertile tillers/plant	22	24	23	20	26
No. fertile tillers per 6″×6″	17	20	19	20	17

The effect of cutting on the seed yield of S.170 tall fescue (H.M.R.)

Interim observations on this investigation were included in the Report for 1956–58, p. 64. The original plan aimed at comparing the yield of seed following cutting the vegetative growth about ½″ above ground level in October, February (representing the stage of growth prior to inflorescence initiation), mid-March (when the inflorescences were visible) and end of March. One series of plots was left uncut. Each variant was subdivided to include two levels of nitrogen applied in the form of Nitro-Chalk at 3 and 6 cwt./acre (= 52 and 104 lb. elemental N.).

Over three successive harvest years cutting in October and February significantly increased the number of fertile tillers and the yield of seed. The following figures represent the mean of the two nitrogen levels during the first, second and third harvest years:

		Cut				
	Control	*October*	*February*	*Mid-March*	*End of March*	*L.S.D*
Mean No. of fertile tillers/ft.	46.2	75.2	54.3	46.6	24.9	7.7*
Mean yield of seed (lb./acre)	414	552	455	428	205	40.2*

* L.S.D. P=0.05

The larger yields following the October and February cuts in the main are due to an increase in the number of fertile tillers, though these heads were shorter than those in the control plots. From the practical angle, numerous small heads and a substantial reduction in bottom growth were advantageous, as lodging was not as severe or as early as in the control plots, thereby easing harvesting especially in a wet season.

Upon the appearance of incipient inflorescences in mid-March, cutting did not materially affect the yield of seed, in fact the data in the first and second harvest years showed a substantial increase following this treatment. Year/defoliation interaction was manifested in a reduced yield in the third harvest. In each harvest, however, the depression of yield after cutting at the end of March was significant at $P = 0.001$, even though very few of the inflorescence tips were removed by the cutting. A large proportion of established heads must have disintegrated after the removal of the foliage to give such a low fertile tiller count.

The results have shown that even with relatively low natural soil fertility S.170 tall fescue can produce good seed yields for the first three harvest years ; its productivity, however, can be further improved by cutting the vegetative growth in the autumn or early winter. In the first harvest year 856 lb. of seed/acre was harvested from this treatment. Doubling the amount of nitrogen gave no significant response in fertile tiller numbers or the yield of seed, but there was a positive reaction in the number of barren tillers, especially following the defoliation at the end of March.

For the fourth, fifth and sixth harvest years, the end of March cutting treatment was replaced by an October cut followed by one in mid-March.

Results from 4th, 5th and 6th Harvest Years

		Cut in				
	Control	*October*	*February*	*Mid-March*	*October and mid-March*	*L.S.D.*
Mean No. of fertile tillers/ft.	57.1	48.9	40.3	42.5	43.4	8.9*
Mean yield of seed (lb./acre)	409	380	361	233	354	41.6*

* P=0.05

The plots cut in October did not produce significantly less seed, but the other three cutting treatments significantly depressed the number of fertile tillers and the yield of seed.

There was a significant increase in the yield of seed following the double cut (October and mid-March) compared with the single cut in mid-March, which indicates the benefit derived from the October treatment. A reduction in yield of grass seed crops with increasing age often occurs, but these results show that older stands also become more sensitive to cutting.

Contributing to the relatively good yield of seed in the control plots was the development of single plant effect by the fourth harvest year. It has been demonstrated that a reduction in plant population favours seed productivity in tall fescue (Evans, 1959, *J. nat. inst. Agric. Bot.* 8, 495–500). It is suggested that within the range of types present the cumulative effect of allowing all the aftermath to remain undisturbed over a number of years may have exerted a selection pressure in favour of the early types.

The seed-bearing potential of meadow fescue and timothy (J.L.)

Plants of S.53 meadow fescue and S.51 timothy were established in pots in the autumn of 1959. In the early spring of 1960 all new tillers were removed at weekly intervals up to the time of anthesis, leaving only five mature tillers per plant for harvesting. These five tillers were allowed to grow uninterrupted, and were subjected to fertilizer treatments at different rates and at different times during the growing season.

Nitro-Chalk at 3 cwt./acre was applied fortnightly commencing on 3 April. Head length was increased by the Nitro-Chalk until four weeks after apex differentiation but once the heads emerged no further response occurred.

Nitro-Chalk at rates equivalent to 2, 4, 6 and 8 cwt./acre given to meadow fescue soon after apex differentiation, and to timothy a fortnight prior to it, produced significant increases in head weight up to 8 cwt./acre. In timothy there was no further response to an additional 2 cwt./acre.

Effects of nitrogen on heading in timothy (J.L.S.)

In a recent paper (Stoddart, 1959) dealing with problems of harvesting in three varieties of timothy it was shown that evenness of ripening was related to the duration of the period of inflorescence, or head emergence, and also that seed yield was closely correlated

with total head-length. It was established that seed set per head was similarly related to head-length, shorter heads bearing less seed per unit length than longer ones. Thus, a factor which tended to increase the percentage of smaller heads *without* a compensating increase in the length of the more mature inflorescences, may have a doubly deleterious effect by reducing seed yield and increasing the range of ripeness.

The known effects of nitrogenous manures upon tillering and size of head in timothy suggested that the magnitude and timing of such dressings might be of paramount importance in determining the total head-length of a plant or crop, and also its distribution amongst a series of arbitrarily chosen head-length categories.

This was tested in a pot experiment using a 5 × 5 split plot Latin square design to study the response of clonally-related single plants of Aberystwyth S.48 timothy (*Phleum pratense* L.) to dressings of 0, 2, 4, 6, and 8 cwt./acre ammonium nitrate applied in September and/or March.

All spring treatments markedly increased the number of heads and total head-length per plant, but autumn dressings had little effect.

Increase in heads and total head-length per plant in response to spring and autumn dressings of ammonium nitrate

Ammonium nitrate (*cwt./acre*)	*Mean No. heads per plant*		*Total head-length per plant* (*cm.*)	
	Spring	*Autumn*	*Spring*	*Autumn*
0	24	19	97.5	78.3
2	48	22	286.2	79.5
4	51	29	344.2	140.8
6	67	27	470.0	95.6
8	74	26	531.4	93.0
L.S.D. (P = 0.05)	13		37.0	
(P = 0.01)	18		49.1	

The autumn/spring interactions of dressings of ammonium nitrate were non-significant for each set of data.

Head-length distribution was greatly influenced by spring nitrogen. The increasing rates of application brought about a proportionate increase in the number of heads over 9 cm. in length, and a reduction in the frequency of those of 4 cm. or less.

A positive correlation between head-length and number of florets per unit length was also established.

Parallel experiments also in pots showed that the clone of S.48 timothy used in the foregoing studies responded to increasing the spring *nitrogen* level by an increase in total number of heads, and also in head-length up to a point which corresponded to a dressing of ammonium nitrate at 18 cwt./acre or 40.7 cwt./acre of Nitro-Chalk (15.5% elemental N). However, 85% of the total head-length increment was obtained by an application of ammonium nitrate at 8 cwt./acre (18 cwt./acre Nitro-Chalk), and up to this point response to applied nitrogen was linear.

Within the range of treatments studied there are good reasons for applying a minimum amount of a nitrogenous fertilizer in autumn and for giving a much greater proportion in the spring, especially when dealing with timothy seed crops prior to the first harvest.

Seed ripeness (G.E.)

In 1960 groups of 100 uniform heads were examined, and it was found that a loss of 40% in seed yield occurred in S.170 tall fescue, and in S.24 perennial ryegrass through shedding when harvested 4 days *after* maximum yield had been reached. The fescue showed a distinct increase in yield during the 4 days previous to the date of maximum yield. Heads of cocksfoot varieties, however, showed a plateau of ripeness extending over a period of 8 or 9 days at near-maximum seed yields. It would appear, therefore, that the latitude for harvesting tall fescue is narrower than that for cocksfoot, and consequently more care is required in order to obtain maximum seed yield from tall fescue.

The number of days from the peak of anthesis to optimum ripeness varied with the species, being again lowest in meadow fescue (18 days), whereas in timothy S.51 no loss of seed occurred *even* 35 days after the anthesis peak. Most of the grass species have shown a cheesy caryopsis at optimum ripeness for maximum yield, but the endosperm of timothy had hardened before any seed shattering had occurred.

The physiology of flowering and stem production in red clover (J.L.S.)

Experiments to date have been concerned with qualitative and quantitative changes in endogenous growth regulators during the process of stem extension and floral induction.

Total ether extracts of clonal material of S.123 red clover were made at various times during the inductive process. *Avena* first

internode (mesocotyl) bioassays on chromatograms of the acidic fraction of these extracts, revealed the presence of at least four growth promoters and one large growth-inhibiting zone.

The greatest growth-promoting activity was located at Rf 0.29 on chromatograms run in an 80% iso-propanol solvent. Further chromatography in a variety of solvents, together with chemical evidence, has indicated that this promoter is identical with synthetic 3,indole-acetic acid (I.A.A.) studied under the same conditions.

During the early stages of floral induction the I.A.A. content of the red clover plant rises rapidly to a high level but falls again almost immediately, the peak of the curve corresponding approximately to the point at which active stem extension commences. It has been consistently observed that the I.A.A. content of a plant and its vegetative activity appear to be closely related. For example, plants growing under short day/high temperature conditions have a much higher I.A.A. content and grow more vigorously than those maintained in a short day/low temperature regime, both groups, however, remain completely vegetative.

The winter dormant condition is characterized on the chromatograms by a low I.A.A. level and a high degree of inhibition in the Rf 0.5–0.6 zone, the much debated and apparently ubiquitous " Inhibitor B " zone, which seems to be connected with dormancy in a wide variety of plant organs.

A most interesting growth promoter was detected at Rf 0.7 when using the 80% iso-propanol solvent, and in all instances its appearance on the chromatograms was correlated with the first visible changes towards the reproductive condition at the shoot apex. Further chromatographic studies indicated that this activity was due to a single substance which was acidic, and gave a pale-grey fluorescence under ultra-violet light.

In lettuce seed germination bioassays it acted as a mild germination inhibitor and also induced a high percentage of root and shoot abnormalities in the seedlings.

The chromatographic behaviour and general properties of this promoter are similar to those of the " Substance E " detected by Harada and Nitsch (*Plant Physiol.* 34, 4, 409–415, 1959) in *Chrysanthemum* and *Rudbeckia*.

Further work aimed at identification and characterization of this substance is now in progress.

Modification of growth habit in red clover by applied growth regulators (J.L.S.)

Previous reports have indicated that a considerable amount of

control can be exercised over the processes of branching and stem extension in red clover by applying gibberellic acid (G.A.) at certain well-defined growth stages (Stoddart, J.L. 1959. *J. agric. Sci.*, 52, 161–167). Whilst many of the induced effects are of potential value, the main objections to the use of this chemical in agricultural practice are, firstly, the excessive cost, and, secondly, the fact that the increased height of the resultant crops would lead to widespread lodging.

The effect of G.A. in increasing the number of heads available for pollination during the first few days of the flowering period is due partly to a premature breakdown of apical dominance in the developing stems, whilst the effect upon emergence is due to a general acceleration of stem and branch internode extension.

Present lines of investigation are centred upon compounds which are known to have similar influences on apical dominance but which have little or no effect upon cell extension. Some success has been obtained this year using 2, 3, 5,tri-iodobenzoic acid (T.I.B.A.) a chemical which appears to act as an anti-auxin when applied to plant tissues.

A foliar spray of 2-5 mg. per plant gave stems which were shorter and had more extensively developed branch systems than the controls. This resulted in the emergence of a high percentage of the total heads during the first ten days of the flowering period. It was necessary to apply the spray during the extension of the 4th to 6th internodes, earlier or later treatments had undesirable formative effects upon the leaves or emerging heads. The mean emergence date of the first three heads per plant so treated did not differ significantly from that of the controls and this raises the possibility of a combined G.A./T.I.B.A. treatment which would give plants earlier in emergence and with shorter stems.

It now seems distinctly possible that a ' temporary mutation ' from the late-flowering to the early-flowering form for the purpose of seed production in red clover might be achieved by chemical means, or, alternatively, that stature-reducing agents such as T.I.B.A. could be used to make such crops more suitable for direct combine harvesting.

PLANT PATHOLOGY

A. J. H. Carr

Clover phyllody virus

Surveys of the effect of this virus on clover seed crops have been continued in 1960 in collaboration with the National Agricultural Advisory Service. Data analysed from records supplied by N.A.A.S. seed inspectors show similar trends to the 1959 Survey, and have confirmed many of the earlier conclusions. Phyllody was again present in about 40% of white clover seed stands, and was frequent to severe in 10%. There was a greater incidence in East Anglia and the West Midlands, areas of intensive white clover seed production, than elsewhere. The disease was more prevalent in older stands, and large-leaved varieties appeared to be more prone to infection than wild white types. Spatial isolation resulting from sowing a grass companion with the crop reduced the amount of phyllody. The virus was recorded in 16 out of 86 red clover seed crops inspected, 8 of which were in the Cotswold area. A more intensive survey was also undertaken in 1960 by N.A.A.S. Plant Pathologists on 52 white clover seed crops, in which critical estimates were made of the percentage of flower heads with phyllody symptoms. This survey was made on selected crops and not at random, therefore no estimate of the mean frequency of infection could be made, but many crops had over 10% of flower heads showing symptoms, and one crop had 27%. It may be concluded therefore that phyllody is capable of building up in a white clover crop to a level at which seed production would be adversely affected.

Research on the virus has been concentrated on the morphological and physiological effects of the pathogen on the host, on methods of control, and on breeding for resistance. Morphological and anatomical studies have shown that the calyx and gynoecium are the most commonly affected organs, the corolla generally being simply reduced and the androecium often distorted but morphologically distinct and functional. Sepals are commonly phylloid, but may be modified into true leaves. The carpels are sometimes greatly hypertrophied and sometimes completely foliacious, with some gradation between these two conditions. Ovules are usually non-functional and may assume a phylloid form. Several affected flower heads showed abnormal meristem development at the base of the gynoecium, and in an extreme condition, termed ' cauliflower ', abnormal multiple meristems were formed on each floret initial,

giving rise to a much reduced floral axis in which the floral organs were completely rudimentary. Contrary to an earlier opinion, the various types of symptoms are not discrete, but exhibit an almost continuous range, and sometimes all types are on one plant and even in a single flower head.

Experiments conducted in collaboration with Mr. J. L. Stoddart (Seed Multiplication) have established that the level of growth-promoting substances (3,indole-acetic acid and other indole compounds) is considerably higher in flower buds from phyllody-infected plants of white clover, red clover and strawberry clover than in flower buds from healthy plants of these species. The greatest amounts of I.A.A. have been obtained from buds with cauliflower-type symptoms, where there is greatest meristematic development, presumably associated with the high hormone level. Spraying healthy plants with I.A.A. (100 mg./1.) resulted in vegetative proliferation of the floral organs similar to phyllody in both white and red clovers, and in the latter a 'cauliflower' inflorescence was produced by this treatment. Present evidence indicates that the probable action of the virus is to cause the hormone level to remain high during the reproductive phase, whereas in healthy plants the level declines from a peak during active vegetative growth to a low value with the onset of flowering. It is hoped that these studies will lead to the elucidation of the biochemical processes involved in the interaction of this virus with its host, and the possibility of controlling symptom expression through adjustment of the physiological balance.

Attempts to control the jassid vectors of phyllody by insecticides have been discussed in the Annual Report for 1959 (p. 63). There remains the possibility of control by breeding varieties which are either resistant or tolerant to the virus or resistant to the vector. So far, no genotype of white clover has been isolated which shows resistance or tolerance to phyllody, but experiments to test the possibility of breeding for vector resistance have met with some preliminary success. Two plants from each of 6 varieties of white clover were cloned, so that each of the 5 replicates isolated inside an insect-proof cage contained 12 plants trimmed to about equal size. Approximately 100 leaf-hoppers (*Euscelis lineolatus*) were introduced into each cage, and 48 hours later the distribution of the insects on the plants was recorded. The mean number per plant varied from 10 to 3, according to clone, with higher populations on certain of the large-leaved varieties and fewer on the wild white types. Although no plant was completely free of insects, these

preliminary data suggest that the possibility of breeding for resistance to the vector is worthy of more extensive investigation. It was also of interest to note that the lowest counts were from wild white clover, which appears from field observations to have a lower incidence of phyllody than the large-leaved types.

Induced mutation in *Puccinia coronata avenae*

One of the major problems of breeding for resistance to the cereal rusts is the evolution of new physiologic races. These have been shown to arise by hybridization of existing races, heterokaryosis and the parasexual cycle, but all of these mechanisms depend ultimately on mutation for the supply of new genetic factors for pathogenicity. Apart from the work of Flor (*Science* 124, 888–889, 1956 ; *Phytopathology* 48, 297–301, 1958 ; *Phytopathology* 50, 603–605, 1960) on flax rust, there are very few records of induced mutations in rust fungi, and consequently, in collaboration with Dr. D. J. Griffiths (Cereals, Beans and *Brassicae*), an investigation was undertaken to obtain pathogenicity mutants in the oat crown rust fungus, *Puccinia coronata avenae.*

As a result of ultra-violet irradiation of uredospores of *P. coronata avenae* Race 96, followed by screening through the Race 96-resistant variety Landhafer, one uredospore culture was obtained which attacked Landhafer and proved in subsequent tests to attack 5 other Race 96-resistant varieties of the standard differential host series. An interesting feature was that the Race 96-susceptible diploid variety Saia proved to be resistant to the UV-induced mutant culture. The reactions of this mutant from Race 96 on the standard series of 10 differential oat varieties were identical with those of Race 277, previously reported only from Israel and Argentina.

These results indicate that induced mutations in *P. coronata avenae* appear to be obtainable with comparative ease, and that they are comparable with naturally-occurring pathogenicity mutants. Further, since the mutation was from avirulence to virulence on 5 oat varieties known to have genes at several different loci controlling resistance, and since also the reaction was reversed on the variety Saia, the theory of complementary genes in host and parasite as postulated for the flax rust interaction is not tenable for crown rust of oats, except in the unlikely event that the mutation involved several loci.

CHEMISTRY

G. ap Griffith

During the year the soil survey of Plas Gogerddan experimental land was completed. Maps have been drawn for each field depicting on a 50 ft. grid the pH and the calcium, phosphate, potash, and organic matter content in the top six inches of the soil.

Work continued on the problem of nitrate accumulation in different herbage species. A field experiment was carried out by Mr. R. J. K. Walters (Grassland Agronomy) to investigate the effect of season and of nitrate of soda, sulphate of ammonia, and urea on the accumulation of nitrate in perennial ryegrass S.23 and S.24, cocksfoot S.143, and timothy S.48 grown in pure swards.

In the first harvest year (1960) the grasses under all the nitrogen treatments showed nitrate accumulation at a high level in spring and autumn (highest peak in autumn), with a marked decrease in mid-summer. Nitrate of soda showed the greatest tendency to induce nitrate accumulation. Previous work (ap Griffith 1960a) indicated that the application of nitrogen in the ammonium form is no guarantee against nitrate accumulation. Mr. Walters's results bear this out, but show that there is more nitrate accumulation when the nitrogen is applied in the nitrate form. Differences between the grasses in nitrate accumulation were well marked, and as in earlier work (ap Griffith *Nature, Lond.*, 182, 1099–1100, 1958), cocksfoot S.143 proved to be the highest in nitrate content.

In collaboration with Mr. T. D. Johnston (Cereals, Beans and *Brassicae*), a study was made of the nitrate content of rape and kale. The results showed, amongst other things, that the stem had the highest content of nitrate, and the midrib of the leaf was richer in nitrate than the leafy lamina (ap Griffith and Johnston, 1960).

Material supplied by the courtesy of Mr. W. Dermott, N.A.A.S., Bangor, from three centres where experiments on kale had been carried out by N.A.A.S., showed some of the highest nitrate contents yet found (over 0.6% nitrate nitrogen). In these experiments the nitrate content increased with nitrogen application, and there was a very close relation between nitrate content and crude protein content. At only one centre was there a response in dry matter yield to the application of nitrogen ; the curve plotted was of the usual logarithmic type. At the point where the yield curve flattened off nitrate accumulation increased markedly. Re-examination of data from a previous experiment on grass (ap Griffith, 1960c) showed

a similar tendency for nitrate to rise when the limit of dry matter increase had been reached.

During the year we received from a Scottish farm a sample of rape from a crop which had been grazed by 200 lambs of which 11 had died. An analysis of the sample proved to have 0.35% nitrate nitrogen, and there is good reason to think that death was due to this cause.

In the Report for 1959 (p. 67) mention was made of the possibility of reducing the number of crude protein determinations by bulking samples from replicated plots in a field trial. The results from replicates bulked in different combinations were examined statistically by Mr. D. G. Miles (Grassland Agronomy). The conclusion arrived at was that the pooling of replicates to reduce the number of samples for chemical analysis can only be justified when the constituent to be determined is only of secondary importance in the results of the field experiments.

CYTOLOGY

Professor P. T. Thomas

The work of this Section has been carried on by Mr. C. P. Carroll and his colleagues since July 1960, when Dr. Keith Jones left the Station to establish a Cytology Department at the Royal Botanic Gardens, Kew.

Considerable importance has been attached during this year to investigations having practical implications for the breeder.

Cytological surveys of basic plants of different bred varieties of ryegrass show a proportion of plants in each variety which produce some inviable pollen. This is in contrast to the situation in short-lived commercial varieties in which continued management for seed production has led to the selection of plants with high fertility. The results indicate the importance of assessing the fertility of all potential parents of new varieties, especially when selection is intense for vegetative characters.

Correlated response to extreme selection

In collaboration with Dr. J. P. Cooper (Developmental Genetics) cytological studies are being carried out on ryegrass which he has subjected to stringent selection for early and late flowering. This type of selection is accompanied by developmental abnormalities both before and during meiosis. These disturbances result in pollen sterility, but sterile pollen can also be produced after apparently normal meiosis. A marked reduction in chiasma frequency has occurred in only one of the lines after six generations of selection.

Dactylis

Natural population sampling. Several additions have been made to the list of chromosome counts of plants derived from collections made over the natural range of the genus, and these have included a hexaploid form from N. Africa. The data collected up to the present time have been used in the preparation of a distribution map of the chromosome races in the genus, which will be published in the near future.

Utilization of Dactylis glomerata *subsp.* lusitanica. The favourable winter growth characteristics of subsp. *lusitanica* amply justify its utilization as breeding material, and with this end in view a chromosome-doubling programme has been initiated. Colchicined

material has been subjected to intensive cytological screening which is still in progress. Eight hundred and fifty separate determinations have yielded 39 pure autotetraploid clones, representing four genotypes, of subsp. *lusitanica*, together with four amphiploid clones, representing three genotypes of the hybrid between subsp. *lusitanica* and subsp. *aschersoniana*. As these tetraploid plants have been derived from wild *Dactylis* subsp. with a high degree of heterozygosity there should be ample genetic material available for hybridization and further development. Plants from successive generations of the two chromosome-doubled forms will be retained in an experimental plot so that meiosis can be compared under similar conditions, and changes which may occur in chromosome-pairing behaviour can be examined.

Festuca and *Lolium* subsp. : Production of chromosome-doubled plants

Colchicined material of *L. multiflorum* and *L. perenne*, and of *F. pratensis* and *F. arundinacea* has been screened for doubled individuals. Seeds were treated with colchicine at germination, and the resultant plants were allowed to grow to a good size. Single tillers were taken from clumps which showed some phenotypic evidence of possible doubling. Seventy-two doubled plants were located in this way, of which 10 were definitely poikiloploid, though others may also have contained $2n$ as well as $4n$ tissue. This work was done in conjunction with Mr. Elfed J. Lewis (Grass Breeding).

Avena

Stabilization of aneuploid lines. This investigation concerns aneuploid lines with 44, 45 or 46 chromosomes which have arisen indirectly through hybridization of a tetraploid with a hexaploid oat. It is hoped that a line may be produced with a constant chromosome number higher than the usual $2n = 42$. Results so far suggest that the even-numbered lines ($2n = 44, 46$) will be the most promising.

Sterility of oats in sand culture. During an experiment on the influence of manganese levels in nutrition, material was fixed from commercial varieties of oats grown in sand culture which had failed to set seed in 1959. The plants set seed normally under similar conditions in 1960 and there was no sign of the suspected male sterility. The cause of the failure of seed set in the previous season is not known.

Cytology of hybrids between plants at different polyploid levels

This investigation centres around a series of autotriploid plants of *Anthoxanthum* which are unique in possessing functional pollen and dehiscent anthers. Pollen stainability is in the range 60–100%, and heavy seed has been obtained by using the triploid as male parent. Meiosis shows the usual triploid irregularities, and information is being collected on the process of disjunction. Chromosome counts at pollen mitosis are being made to ascertain whether selective elimination of gametes occurs between this stage and the completed zygote. Seed from backcrosses to the 2x and 4x parents made during the summer is ready for sowing so that chromosome numbers can be determined. There is some evidence that the triploid is more successful as a male than as a female parent, and as this could have practical implications for *Dactylis*, certain more fertile *Dactylis* triploids have been selected for use as male parents in crosses. The pollen will be dissected from the indehiscent anthers. The *Anthoxanthum* material is particularly valuable because for the first time it provides the possibility of a direct comparison between male and female gamete production and behaviour in triploids, which recent studies have shown to be of considerable importance in evolution.

DEVELOPMENT OF SEED AUTHENTICATION

Gwilym Evans

Official authentication of seed crops is comparatively new but supplies of authentic seeds have long been available.

In former times the farmer who held the highest status was not the skilled breeder of farm stock but the man who could be relied upon to supply seed corn well adapted for the region. It was realized that appearance in seeds was apt to be more misleading than in the farm stock of those days ; a variety is seldom identified by its seed.

The philosophy that home-grown seed was best became so firmly established that farmers were convinced that the cropping value of a red clover was wholly due to the seed having been produced in their particular climate and soil. It was not appreciated that that was a long-term effect, and that the high reputation in which a local clover was held might have a deeper significance. The idea that there were in fact different and distinct varieties within a species of grass or clover was very slow to be recognized. For many generations grass seed from old pastures in Kent had been harvested carefully and given high priority for re-seeding good quality swards. The seeds of the various grasses were regarded as the most important, while the white clover had to take second place. It became clear later that here was a valuable pasture type of rye-grass not available elsewhere, and that the home-grown seed of white clover could persist in the soil through a rotation, and become available as a constituent of a pasture without the need of having to sow the seed.

Douglas Gilchrist in 1891, whilst at the University College of North Wales, Bangor, saw an experiment conducted on the Hawarden Estate of W. E. Gladstone which showed that white clover seed from old pastures in Kent sown with perennial ryegrass persisted and made a first class sward even after 5 years of grazing, whereas the white Dutch clover had long disappeared (Gilchrist, 1909). Thus the existence of varietal differences among separate populations of herbage plants was shown in unmistakable fashion. Gilchrist himself started trials with wild white clover in North Wales in 1893 (Nichol, 1951). By a singular coincidence, the phenomenal effect on white clover in pastures of the basic slag, which was produced as the result of experiments by Sidney Gilchrist Thomas, became widely known about the same time. Basic slag in quantity

became available to benefit agriculture more rapidly than the wild white clover seed could be produced, for by 1890 623,000 tons of basic slag had been produced, and most of it used for agricultural purposes (Burnie, 1891). There appears to be no record of parcels of Kent wild white clover seed having been sold outside the county before 1906, although it is recorded that within the county wild white clover seed was sold from one seed firm to another in 1865 at 54/– per bushel (Eastes & Loud, 1944).

The first chapter in the history of formal authentication of seed crops in Britain was written as a result of the clover variety trials conducted at Aberystwyth from 1919 to 1922 (Williams, 1927). These critical trials showed two things very clearly. The first was that several distinct types of clover were being grown for seed in different parts of England and Wales, ranging from early-flowering types to extra-late-flowering varieties with intermediate types as well. In Wales there were the typical extra-late-flowering red clover of Montgomeryshire, the medium-early of the Vale of Clwyd in North Wales and the early red of Glamorgan. Among the varieties in England there were the late-flowering Cotswolds and Essex types, and many local stocks of typical early reds, with an extra-late-flowering variety in Cornwall (Cornish Marl).

Secondly, the data proved that our native clover varieties were well adapted to our conditions and superior in performance to foreign clovers. Thus convinced that British Agriculture would derive substantial benefit from the use of larger seed supplies of these valuable indigenous varieties, the Welsh Plant Breeding Station advocated and sponsored the formation of Seed Growers' Associations for the production and authentication of seed of local varieties. The two first societies were established in 1922, namely the Montgomeryshire Late-flowering Red Clover Seed Growers' Association (Proposal for establishing Montgomery Red Clover Seed Association. *Mark Lane Expr.* 20 Feb., 1922), and the Vale of Clwyd Association (First Minute Book Vale of Clwyd Red Clover Seed Association, 15 March 1922). Several associations were established later in England under the influence of the Welsh Plant Breeding Station, and with the active help of its staff over a period of years in the matter of seed crop inspections.

No one appreciated the full significance of seed crop authentication until R. D. Williams, the Station's clover breeder, had examined in detail a large number of seed crops submitted for inspection by associations (Williams, 1923). On the basis of this experience Williams made two very important generalizations.

Firstly, that crops of a so-called local clover varied enormously in type. The spurious minority of crops was undoubtedly sold on the reputation of the typical crops, simply because they were ' grown in the district '. They were grown, sold and purchased in ' good faith ' possibly from the same untypical stock for several generations. Therefore, ' good faith ' does not seem to be a sound basis for trading in seeds which contribute so largely to the success or failure of the farmer. Seed crop inspection and certification, on the other hand, regularize business in seeds and bring confidence to vendors and users. Secondly, R. D. Williams was impressed by the remarkable varietal purity of many of the crops examined. That was an excellent starting point for increasing the seed supplies of local varieties on an organized basis. By making future inspections conditional upon the use of seed from the most typical of the certified crops as indicated by the inspector, the growers' societies were able to standardize their product and enhance its reputation, for the purchaser was now guaranteed that he received the variety he had ordered and for which he was paying at a premium.

In addition to certifying and marketing the crops the societies raised the standard of seed husbandry through meetings convened for discussions on various aspects of seed production and provided trophies for the best crops submitted for inspection. The success and progress of a society, however, was retarded when it failed to organize reserves of stock seed of its own variety adequate to cover bad harvests, or a sequence of bad harvests, and to fulfil the sowing needs of its members each year, and in general the demands of its clientele. Such a weakness is not peculiar to seed growers' associations, and leads to the danger of growing seeds from doubtful stocks.

The next development in seed crop certification began through W. T. Price, the then Agricultural Education Officer for Wiltshire. When R. D. Williams and Gwilym Evans of the Welsh Plant Breeding Station were invited to inspect white clover pastures in Wiltshire in the summer of 1929, they spent several days in the examination of many fields which the growers thought suitable for producing wild white clover seed, and were able to authenticate the type as genuine wild white for which no county appeared to have a monopoly. One of the most interesting fields examined was an old foggy down which A. G. Street had ' hosiered ' (after the manner of A. J. Hosier) thoroughly for twelve months with the result that at the time of inspection it was covered with the bloom of genuine wild white clover. Fifty-five acres of an excellent type of clover were also certified for A. J. Hosier.

Following a discussion in Wiltshire between the two officers from Aberystwyth and Regional Seed Inspectors of the Ministry of Agriculture, the National Wild White Clover Certification Scheme was inaugurated in 1930 by the Ministry of Agriculture in conjunction with the National Farmers' Union. Two grades of seed were established under the scheme, *Grade A*, for pastures 10 years old or over, and *Grade B*, for pastures under 10 years old but sown with wild white clover seed. The importance of field crop inspection was clearly shown by the range of white clover types in the different leys submitted for inspection. For example, the writer found one pasture in Yorkshire which contained a clover type widely different from wild white although it had been sown several years previously. The grower admitted having sown ' giant white ' clover which had survived probably by re-seeding. Another field near Market Harborough carried an excellent sward over 10 years old, with an abundance of white clover. Under the prevailing conditions this particular clover was much superior to the wild white type, but it could not be certified as the latter as it was distinctly different.

Intermediate types of white clover were frequently found, especially in areas of relatively short arable rotations. Without an inspection scheme neither the grower nor the seed merchant can be certain of the type harvested and offered for sale in good faith. In seasons highly favourable to the production of clover seed considerable quantities of valuable white clover seed are harvested as salvage crops from pastures of various ages. These crops would be more valuable if the types were identified and guaranteed under the National Scheme so that proper use could be made of each lot.

The certification of local varieties of red and wild white clover seed made a considerable impact on the seed industry. Growers and vendors were becoming generally more variety conscious and aware of the need for greater care in maintaining the identity and purity of seed stocks. This progressive attitude was greatly strengthened by the release for seed production of varieties of grasses and clovers bred by the Welsh Plant Breeding Station.

In July 1931 members of the Seed Trade Association of the U.K. visited the Station; they were impressed by the superiority of the new varieties for British agriculture, and by their ability to produce satisfactory seed crops.

It was in 1932 that the first new varieties were put on the market, they were :

Perennial ryegrass	S.23
Cocksfoot	S.26

Timothy	S.48, S.50, S.51
Meadow fescue	S.53
Red fescue	S.59

Others followed in due time, so that in 1960 there are three varieties each of perennial ryegrass, cocksfoot and timothy, two of meadow fescue, one each of Italian ryegrass, red fescue and tall fescue, two each of red and white clover. These became listed in seedsmen's catalogues alongside certified local varieties of red clover and wild white clover. A few forward-looking seedsmen had sufficient faith in the leafy varieties to persuade selected farmers to grow seed for them on contract, and thereby was started a new industry in many parts of the country.

During the Second World War seed merchants and growers responded with energy to the call for ensuring the nation's seed supplies. This campaign very deeply involved the Seed Production Officers of the Station, for it became urgent to obtain a rapid increase in the supplies of Stock Seed of the Aberystwyth herbage varieties. It was necessary, therefore, in order to fulfil national needs to contract for growing the seed on a wide scale over many counties within a radius of 150 miles of Aberystwyth. The seed had to be processed and despatched from the Station to individual growers on behalf of the contracting seed firms. As the fundamental importance of providing authentic seed stocks for multiplication became properly understood and appreciated by the seed industry, great efforts were made to meet this need by acquiring improvised accommodation and seed processing equipment.

Up to 1942 the Aberystwyth Seeds Co-ordinating Committee, covering the whole of Britain, had for several years been engaged in promoting the production and use of *S* varieties. Its trade and grower members had been invited to join the committee not as representatives of particular interests but in their individual capacity as leading practitioners dedicated to seed improvement. In 1942 this Committee came under the aegis of the Seed Production Committee and was renamed the Aberystwyth Seeds Sub-Committee, with representatives from the different sections of the industry. The Aberystwyth Seeds Sub-Committee was charged with the duty of speeding-up the development of seed production of the quality herbage varieties. In addition, the Ministry of Agriculture and Fisheries, as it then was, issued directives to County Agricultural Committees urging them to promote seed growing and encourage the formation of more seed growers associations to strengthen the campaign for national sufficiency in seeds. In furtherance of this

project the members of staff of the Welsh Plant Breeding Station were required to give of their time freely to addressing farmers' meetings all over the country, and take a leading part in field demonstrations of seed production techniques. The response to the campaign was satisfactory in terms of increase in the number of associations and growers. By 1938 the number of seed growers associations was ten (most of them established for the production of seed of Aberystwyth varieties), 22 had been formed by the middle of 1942, and 40 by 1944, including the Lincolnshire Association. (N.I.A.B. Seed Production Committee (1944): Seed Growers' Associations Supplement to Seed Notes No. 8). Many of them became formally registered with rules and regulations governing their activities as independent organizations. Some ultimately became Seed Specialist Branches of the National Farmers' Union, under the care of a headquarters committee of the Union. In Wales in 1942 the associations formed the Welsh Seed Growers' Federation which operates under the auspices of the Welsh Agricultural Organisation Society. A similar attempt during the war years to federate the associations in England did not mature.

Seed certification

British seedsmen in 1940 appealed to the Welsh Plant Breeding Station to inaugurate a seed crop inspection and certification scheme for *S* varieties. The Station, realizing that at that time it was the only competent authority to do the work, responded to the appeal and immediately organized a scheme for the inspection of crops grown in different parts of Britain. All the senior officers of the Station, including the then Acting-Director, Dr. T. J. Jenkin, were enlisted as seed crop inspectors, each being made responsible for a group of counties. The acreage in 1941 was similar to that of 1940 (1570 acres), but in the years immediately following it doubled annually. Inspection work thus became too onerous for the Station's staff, but, fortunately, several Grassland Advisory Officers acquainted with the characteristics of the varieties were made available for a few weeks each year to assist in operating the scheme. These officers were trained as seed crop inspectors in a special course at Aberystwyth and were given a refresher course annually and immediately prior to the beginning of the inspections. As the acreage of seed crops continued to expand, the District Agricultural Advisory Officers were commissioned to augment the inspectorate. The National Institute of Agricultural Botany also placed a number

of its officers at the disposal of the Station for training as inspectors, and they assisted with the work of inspection in the Eastern Counties.

By 1947 the crops submitted for inspection covered over 36,000 acres (Evans, 1958), and 90 officers of the newly-formed National Agricultural Advisory Service, together with 5 officers of the National Institute of Agricultural Botany, attended the Seed Crop Inspectors' Course at Aberystwyth that year prior to inspection. A proportion of these officers were trainees who would accompany the experienced officers on the inspections with a view to becoming fully competent by the following season.

Uniformity of certification

The Station insisted on two basic principles for the operation of the Seed Crop Inspection Scheme, firstly, that only crops grown from authentic multiplication seed were valid for inspection; secondly, that only the crop inspector was competent to determine the trueness to type of the variety.

Toleration standards were established for the field crops in respect of (a) distance isolation from a serious source of offending pollen; (b) extreme off-types in the variety; (c) other useful species in the crop, and (d) weeds. (Seed Crop Certification Scheme [Rules, Regulations and Conditions] 1953. Welsh Plant Breeding Station, U.C.W., in conjunction with the Aberystwyth Seeds Sub-Committee.)

The uniform purity of the crops was greatly promoted by careful pre-inspection of the fields at an appropriate stage before sowing to determine the extent of buried seeds from previous cropping, and of weeds that might prejudice certification, also to verify and approve the isolation.

Multiplication stock

Growers and seed merchants readily accepted the requirement of the Station that as a sound basis for the official certification of herbage seed only crops grown from authentic multiplication seed supplied directly by the breeder, or on his direction, were eligible for inspection under the Scheme. Apart from the various sources of contamination to which crops are liable during multiplication, grass varieties are subject to a shift in type during successive generations (Evans, 1959; see article on p. 99).

The Station's resources were severely strained during the Second World War, and subsequently, in the endeavour to provide as much Stock Seed as possible to meet the increasing demands for

multiplication seed of its bred herbage varieties of 14 grasses and 4 clovers. In 1945 the Station distributed 1,450 lots of seed from Stock Seed crops grown on contract to sow nearly 20,000 acres for seed production. Large as these quantities were, they were insufficient to meet the nation's need, and therefore seed from Certified Crops of outstanding merit was released through the goodwill of the holding seed firms to supplement Stock Seed supplies of some of the varieties, and was distributed for sowing approved fields on the instruction of the Station. Thus in 1946 Stock Seed and Supplementary Multiplication Seed were distributed to sow nearly 25,000 acres.

The Supplementary Multiplication Seed may not always be as high in merit as Stock Seed but it has been the means of providing growers with authentic stocks to grow thousands of tons of most valuable seed to replace the ordinary varieties of commerce for the grasslands of Britain. Growers were most anxious to acquire such supplementary seed to maintain their seed production programmes and were prepared to take any risk that might be attached to it. Furthermore, the growers were also prepared to pay a generous price for Stock Seed, their chief concern being that adequate supplies should be available to them at all times to meet their requirements.

Growers are entitled to the best possible quality seed for multiplication, and to ensure this a new policy has now developed at Aberystwyth to reduce to a minimum the number of generations from the breeder's mother plants to the certified seed stage. It is now possible for the ley farmer to obtain Certified Seed of several of the *S* herbage varieties only *three* generations away from mother plants, thereby guaranteeing both the identity and the generation of the variety. Britain has given a lead to other countries in evolving a pattern for the control of stocks.

Seed Bank

Seed production of herbage plants is beset with many hazards ; seed yields can vary within wide limits from one season to another, and there may be a succession of low yields especially with clover crops in wet seasons. In order to meet various contingencies reserves of Foundation Seed of the *S* varieties have been established from increased acreages and good harvests in favourable seed years. These seeds are processed so that they can be kept in the Seed Bank and maintained in a highly viable condition for several years. Critical experiments conducted at Aberystwyth have shown red clover seed to be capable of 99% germination, and subsequent vigorous growth after 10 years' storage. The seed had been dried to

8% moisture content, sealed in bottles to prevent reabsorption of moisture, and held in cold storage at 1°C. (Evans, 1957a). Perennial ryegrass seed dried to 1.62% moisture content and sealed showed high vigour, and 93% germination after 7 years without cold storage (Evans, 1957b).

In 1954 the National Institute of Agricultural Botany on behalf of the Welsh Plant Breeding Station undertook responsibility for the production and distribution of Stock Seed of the Aberystwyth herbage varieties, and agreed to provide facilities for maintaining adequate reserves of Stock Seed. These reserves were expected to be sufficiently large to allow for (a) the continued expansion of production of bred varieties to replace the seed of the common varieties of commerce without having to resort to supplementary stocks from among certified seed crops, (b) unfavourable harvests for Stock Seed crops with consequent low yields and (c) various hazards causing wastage of Stock Seed crops and reducing below expectation the effective acreages coming for harvest. These Stock Seed reserves represent a valuable service to the seed industry and ley farmers. They should increase the confidence of growers and help to bring about a greater progress in the general use of bred varieties.

Comprehensive certification

During the 15 years in which the Welsh Plant Breeding Station organized and administered the Seed Crop Certification Scheme 287,208 acres of the Aberystwyth varieties were inspected. After 1954, however, responsibility for the administration of the Scheme was transferred to the N.I.A.B. and the Scheme continued to operate under the now Aberystwyth Seeds Committee. A comprehensive Seed Certification Scheme was initiated in 1956 by a new committee designated the National Certifying Authority for Herbage Seeds. (National Certifying Authority for Herbage Seeds, 1956.) The Aberystwyth Seeds Committee continues to control policy in respect of seed production, and to be responsible for the field approval of seed crops, whilst the Certifying Authority has become responsible for the last stage of authentication. Guaranteed seed has thus become available to the farmer in sealed bags with labels carrying the certificate numbers, and the trade mark of British Certified Seed. There is only one grade of British Certified Seed, but certificates may be given for Field Approved crops, even though after processing they do not reach the seed standards of British Certified Seed.

Crop Certification Schemes for local varieties of herbage species continue to be operated in Britain, some on an independent basis, while others function under the Certifying Authority. These local varieties include red clover, white clover, sainfoin and perennial ryegrass.

Meeting national usage of herbage seeds

The pattern of seed requirements has been in a continuous state of flux for many years and a comparison of seedsmen's catalogues issued in 1914 with those of today shows that extraordinary changes have occurred. Certified seeds of local and bred varieties have become contemporary items of commerce and are prominently featured in the catalogues.

In 1959 a record total of 41,780 acres of seed crops of the Aberystwyth varieties was submitted for inspection. These varieties account for over 88% of the national acreage inspected, with about 11% of local varieties, and under 1% of other bred varieties. A considerable proportion of the seed of some of the herbage species used in the United Kingdom is Certified Seed of the Aberystwyth grasses. The percentages of seed of certified *S* varieties grown in 1959 to meet the United Kingdom's total requirements for the following species in the season 1959/60 (calculated from M.A.F.F. Statistics) were :

Species	*Varieties*	*Percentage of Certified Seed grown in U.K.*
Cocksfoot	S.26, S.37, S.143	96
Meadow fescue	S.53, S.215	34
Timothy	S.48, S.50, S.51	24
Italian ryegrass	S.22	18

It will be observed that sufficient seed of Certified *S* varieties of cocksfoot was grown to provide almost all the total weight of cocksfoot for sowing in 1959/60, but nearly 500 tons of this was exported and lost to British agriculture, and this was largely replaced by imported seed of common varieties. The quantity of seed of meadow fescue *S* varieties and Italian ryegrass S.22 produced in England and Wales has shown a distinct upward trend in recent years.

There is ample evidence to prove that we have excellent soil, climate and growers in the United Kingdom to produce all our requirements of grass seeds. We have quality seeds specially bred for our conditions and purposes, for long or short leys and for a long

grazing season. It should not be necessary to import any foreign seed adapted for other climates and purposes if proper arrangements were made to provide our farmers with adequate supplies of home-grown seed of the superior varieties.

Furthermore, all home-grown seed released for sale should be fully authenticated as is done in Holland, and thus provide the farmer with due protection. Most of the foreign surplus does not carry a guarantee of type or performance in this country.

Only about 15% of the red clover varieties used in 1959/60 was authenticated. In good clover seed years England and Wales often produce three times the annual requirement of red clover seed which on average is about sufficient to cover the low yields from poor harvests in unfavourable years. A system has not yet been evolved to secure a national carry-over of good seed covering a period of years, and therefore the surplus seed from bumper harvests continues to be exported, so that we have to depend on foreign varieties when the harvest fails us. If such foreign seed were stained at the port of entry there would be less danger of foreign varieties being grown and harvested in Britain and sold as ' English grown ' varieties which contaminate our valuable indigenous types.

Three measures would undoubtedly help to secure adequate supplies of seed of the herbage varieties with the greatest merits for British farming :

1. Only varieties proved to be superior for our conditions on the basis of official assessments are valid for use in the United Kingdom.

2. Only certified seed of approved varieties is valid for sale to our farmers.

3. Foreign seed imported to correct our short supplies is stained at port of entry.

Such provisions have already been made to protect the farmers of some countries in Western Europe.

Cereal seed certification

The first Cereal Crop Certification Scheme in Britain was developed by the Welsh Plant Breeding Station on the formation of the Clarach Seed Growers' Association, Aberystwyth, in 1933. The first cereal to be authenticated was a variety of *Avena strigosa* S.78 (Ceirch llwyd) improved by selection at the Station. From this modest beginning came the inspiration for the development of

cereal authentication schemes in England, Scotland and Northern Ireland.

Following the lead of the Clarach Seed Growers' Association other seed growers' associations were formed in Wales, one of the most successful being the Hay-Talgarth Association established in 1936. As all the Welsh Societies had federated in 1942 under the title of the Welsh Seed Growers' Federation, they were able to establish the first Comprehensive Seed Certification Scheme in Britain with very high standards for Stock Seed and Certified Seed grades for cereals (Welsh Certified Seed, 1958).

Most leading seed firms in England now operate the Field Approval Scheme for cereals and each firm has its own personnel trained to inspect the crops. A large proportion of the cereal seed now available from seed vendors is from Field Approved crops.

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FACTORS AFFECTING SEED PRODUCTION OF LATE-FLOWERING RED CLOVER

J. L. Stoddart

One of the principal factors limiting the use of late-flowering red clover varieties in the British Isles is the sparsity and uncertainty of seed supplies. For example, the average yield from seed crops of Aberystwyth S.123 late-flowering red clover grown in Lincolnshire during the period 1948–1958 is quoted by the Lincolnshire Seed Growers' Association (1958) as 1.77 cwt./acre, with the lowest annual average yield of 45 lb./acre in 1956. In 1959, an outstanding year, yields of 5 to 6½ cwt./acre of clean seed were obtained from crops of S.123 grown under contract for the Welsh Plant Breeding Station, and some experimental plots gave yields in excess of 10 cwt./acre (*Rep. W.P.B.S.* 1959, p. 60).

The magnitude of the seed yield obtained from a given crop is determined by a complex interaction of variables, but if establishment is satisfactory then low yields are generally due to one or more of the following factors (i) an inadequacy of pollinating agents during flowering; (ii) a low number of blooms per unit area; (iii) unfavourable weather conditions during pollination and seed ripening.

Until comparatively recently it was thought that only wild bees were capable of efficiently pollinating red clover, and managements were based upon cutting and grazing systems which would ensure that the full bloom period of the crop coincided with the peak population of wild bee pollinators. Williams (1925) showed that the peak of the wild bee population occurred about three weeks after English late-flowering red clover was in full bloom, and five weeks after English broad red had reached the same stage. He was of the opinion that yield could be enhanced by postponing the flowering period by suitable cutting or grazing treatments so that the crop came into head during the optimum pollinating period. Whilst this approach to the problem is undoubtedly sound in theory, a weakness lies in the implied suggestion that the full bloom period of each variety and the peak bee population are separated by a rigid and immutable time interval. Where this interval is wide, as in broad red varieties, such an assumption is of little consequence, but where the separation is narrow, as in Montgomery or S.123, it becomes untenable.

If it is assumed that climatic factors do not affect the timing of either the full bloom period or the peak of bee population it must

also be contended that crops which are allowed to flower freely without previous defoliation would set very little seed in comparison with those in which flowering was postponed by suitable management. To test this, simple experiments were conducted in which S.123 red clover sown at 2 lb./acre in 2′ 6″ drills was allowed to flower freely and also was subjected to a simulated silage cut at the end of May. Data were collected in a dry year (1959) and in a wet year (1960) in order that a true comparison could be made. The yields obtained are given in Table 1.

Table 1. *Comparison of seed yields obtained from first growth and aftermath of S.*123 *red clover*

	Yield (lb./acre)	
	1959	1960
First growth	884.6	127.4
Aftermath growth (cut 30 May)	414.4	44.2
L.S.D. (P = 0.05)	268.8	77.5

Almost all the pollination was carried out by wild bees, the most frequent species being *Bombus terrestris, B. agrorum* and *B. lapidarius*. Thus it seems that the common practice of taking a silage cut at the end of May, or possibly grazing up to this date, is detrimental rather than beneficial to seed yields, and, furthermore, that a successful degree of seed setting can be achieved before the reported time of the peak of wild bee population.

Leaving on one side considerations of pollination, it is clear from a theoretical standpoint that the number of red clover blossoms per plant produced in the aftermath or in the seed crop will be closely related to the height of the crop when cut for silage, or to the severity of grazing. Recovery is dependent upon the number of axillary buds and vegetative tiller apices remaining below the cutting level. This can be illustrated by a glasshouse experiment in which plants were cut back to varying heights at the emergence of the terminal head :

Table 2. *Flower production in single plants of S.*123 *red clover related to height of cutting*

Height of cut (in.)	*Total flowers per plant*
1	11.5
2	18.3
4	51.7
Control (no cut)	131.3
L.S.D. (P = 0.01)	30.9

The effect of cutting treatments is more accentuated in the glasshouse than in the field, but nevertheless the figures demonstrate that cutting over a wide range of heights reduced potential seed yield when this is measured in terms of flower number.

Seiffert and Skirde (1959) have shown that such treatments result in an increase in the number of florets per flower head but the maximum increment observed was only of the order of 10% and, therefore, of little significance in compensating for the reduction in flower number. Counts in 1960 made on the drills used for the experiments described in Table 1 revealed that there was an average of 183 flowers per sq. yd. in the free-flowering drills, compared with 98 per sq. yd. in those cut back to a height of 2″ on 30 May.

In order to obtain even ripening it is necessary that the duration of flowering be as short as is compatible with adequate pollination. In 1960 this period was 38 days in the free-flowering material, and 55 days in the aftermath drills. The seed from the undefoliated drills was harvested appreciably earlier in both years.

Until recently the mass of leafage produced by ungrazed seed crops would have proved to be a major drawback, but the advances made in crop desiccation techniques during the last few years have done much to remove this handicap. It is possible that the advantage of grazing in producing a crop which is short in stem, and therefore more resistant to lodging, will be nullified by the use of certain relatively inexpensive chemicals. This is now being studied at Aberystwyth.

In free-flowering stands plant density, which affects stem, flower and branch production is one of the principal factors determining the number of blooms produced per unit area (Table 3).

Table 3. Effect of plant density on stem, flower and branch production

Density (*Plants/sq. ft.*)	*Stems*	*Flowers*	*Position of lowest branch*
	Per sq. ft.		
1	34.7	169.2	Node 2
3	70.5	326.2	,, 3
4	57.0	233.0	,, 4
5	56.2	245.0	,, 5
L.S.D. (P = 0.05)	11.56	51.01	–

The table shows that optimum flowering is obtained with a population of three plants/sq. ft., but that a fall in stem and flower production occurs when density rises above, or falls below, this figure. It is rare to find a field crop of red clover with a population density of less than four plants per sq. ft., and it follows, therefore, that the full head-producing potential is not realized in the majority of crops of this species. This was demonstrated by field observations made recently on two first harvest year crops of Aberystwyth S.123 growing within two miles of one another in Herefordshire. The first was sown at 2 lb./acre in drills spaced 24″ apart resulting in a stand with 4.4 plants, 62.4 stems and 206.0 heads per sq. ft. In comparison, the second crop had been sown broadcast at 6 lb./acre and had 9.0 plants, 45.8 stems and 103.8 heads per sq. ft. These differences were all significant, and show very clearly the marked effect which excessively large plant populations can have upon flower production under field conditions.

Whilst it is possible to obtain reasonable seed yields from red clover by relying solely upon pollination by wild bees it is obvious that the potential yield in terms of the number of blooms produced far exceeds the capabilities of the number of pollinators available. It has been calculated that during the peak of the flowering period in a red clover crop about 45 million florets per acre develop each day (Åkerberg and Hahlin 1953). It is not surprising, therefore, that a widespread effort has been devoted to finding methods of increasing the pollinating force during the period such crops are in full bloom. There has been a great deal of controversy over the effectiveness or otherwise of domestic (or honey) bees. For some time it was supposed that they merely followed the so-called ' robber' bees (*B. terrestris*) and obtained nectar through the holes left by this species. This contention was strengthened by studies which showed that the tongues of the domestic bee were too short to enable them to gather nectar when working from the mouth of the corolla tube. The consensus of opinion now is that under certain well-defined conditions the honey bee can be a very effective pollinator of red clover (Butler 1945), and that the placement of hives on the field at the commencement of flowering results in increased seed yield (MacVicar *et al.* 1952). The efficacy of the honey bee is dependent on the absence from the vicinity of white clover blooms or similar sources of more accessible nectar, and this can be ensured by the enforcement of suitable isolation standards.

In the light of the findings discussed in this paper it becomes clear that a critical reappraisal of late-flowering red clover seed-

growing techniques is long overdue, and it is hoped that these pilot experiments will add impetus to this urgent problem. It is not sufficient simply to blame the weather and leave it at that.

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SHIFT AND THE PRODUCTION OF AUTHENTICATED SEED OF HERBAGE CULTIVARS

Gwilym Evans, W. Ellis Davies and A. H. Charles

The full benefits of improved herbage cultivars can only be realized when adequate supplies of authentic seed of high quality are available to the farmer. High quality includes trueness to type, good germination, purity, with freedom from noxious weeds and seed-borne diseases. In the self-fertile cereals trueness to type generally indicates the absence of mechanical admixture of other species and varieties.

In addition to mechanical admixture with other seeds a lack of trueness to type in the cross-breeding herbage varieties may reflect a change, or shift, within the variety itself, so that it no longer conforms to the original published description (Evans, 1949). This is because each plant in an outcrossing variety is a hybrid and carries within its constitution a wealth of variation. The amount of variation is consciously limited by the breeder, who recognizes that each population develops an equilibrium with its environment and therefore a developmental stability is maintained within the variety. This stability, however, is only maintained as long as the operative selection pressures remain the same. If these are permanently changed, new equilibria will be reached.

The great wealth of potential variation within each outcrossed plant can be released in a few generations (Beddows, 1958; Cooper, 1959b). The herbage varieties bred at the Station have been based on more than one plant, and breeders have used a large number to avoid the dangers of inbreeding depression which is inherent in these outbreeding species. In spite of the limits determined by the breeders the total potential variation in any one variety may still be very large. In addition, the rate of multiplication of herbage varieties is such that before there is a sufficient quantity of seed available for marketing, a minimum of three to four generations has to be produced. The cultural conditions under which multiplication is carried out are often extremely different from those for which the variety is used agriculturally. For instance, a grass variety which is normally sown with a clover and grazed at a height of 4″ – 6″ may for seed production be grown in wide drills without clover, given heavy dressings of nitrogenous fertilizer, and allowed to reach full maturity. The selection pressures under these conditions are

entirely different and during 3 or 4 generations might considerably change the nature of the variety.

Because of these possibilities it is important that there is complete control at all stages of multiplication, and frequent checks made on the final product. The underlying causes of these changes during multiplication need to be studied to avoid some of the pitfalls.

One striking example of such change is illustrated in Plate 1 facing p. 106. The two top photographs show wild white clover in its first and second harvest years. In the left picture there are 2 rows (20 plants) of genuine Kent wild white clover, and one row (10 plants) grown from a stock of the same name from a sample sent to the Station and alleged to have been multiplied outside its region of origin. In the right picture it can be seen that in the second harvest year the 20 plants of genuine Kent wild white have maintained their characteristic persistence, while the row of 10 plants from the foreign-grown seed has almost completely lost its cardinal virtue of persistence, although described as ' Kent wild white clover.'

The combination of factors involved in this example is rather obscure, but it is clear that the foreign-grown material did not last beyond the first harvest year. Without a system of qualitative control, seed grown outside its region of origin could be sold in good faith with disappointing results, reduced profits for the farmer and a consequent loss of confidence in the seed supplier.

The Station obtained clear evidence recently of the deterioration in type that can occur when seed of a grass variety is produced outside the country of origin. Plants grown from 18 lots of Aberystwyth S.143 cocksfoot seed produced and certified in U.S.A. were compared at the Station with standard stocks. They were found to have lost their original character to such an extent that they approached nearer in type to ordinary Danish cocksfoot than to the United Kingdom stocks of S.143, being taller, much less leafy, and earlier in heading (Plate 1, bottom left), (Evans and Beddows 1958).

It is the purpose of this paper to discuss some of the underlying causes of shift, and so assist our understanding of the problem.

Variation within the variety

The total variation in a variety will depend on the number and constitution of the basic plants. Selection within an ecotype should provide more stable material than selection of phenotypically-similar plants from different ecotypes. Varieties with a short generation time, such as Irish ryegrass (Cooper, 1959b) or red clover,

will have reached a greater developmental stability than a variety with a very long generation time such as Kent ryegrass, where the plants present in the sward may have been there for decades. In particular the polygenic control of most agronomic characters, and the outbreeding nature of the crop, mean that much potential genetic variation can be carried in a small group of plants. Intense selection acting on this variation can produce within a few generations a population whose range of variation is completely outside that of the parent material (Cooper, 1959b).

The variation in characters directly concerning rate of reproduction, such as number of flowers and percentage fertility, can be expected to result in a rapid change in frequencies of associated characters during multiplication. Davies (1954) has shown that the percentage fertility of basic plants of S.23 ryegrass varied from 12% to 76%, and similar differences have been observed in white clover (Dessureaux 1950). Large differences in seed yield of individual basic plants have been observed in white clover (Laude and Stanford, 1960).

The effect of seed multiplication on the stability of the pattern of variation within a variety has received considerable attention at Aberystwyth in recent years. Investigations on the range of plants constituting a grass variety have shown that some plants may produce considerably higher seed yields than others. For example, in a leafy variety of cocksfoot the heaviest seed-yielding plants produced over three times the quantity of seed of the lowest yielding over a period of three years.

The seed yields of early-heading plants within bred varieties of cocksfoot, tall fescue, meadow foxtail and *Phalaris* hybrid were greater than those of the late-heading plants. For example, the early-heading plants of *Phalaris* gave 80% more seed than the late plants. Tall plants within a variety of timothy gave higher seed yields than squat plants. Thus the proportion of tall plants could be expected to increase with each generation of these varieties under the ordinary farm management prevailing for seed production at the present time.

Variability within a variety may have a very marked influence on its stability; a distinct tendency to produce heavier seed yields, combined with earlier heading, has been found in successive generations of high-tillering, late-heading grass varieties (Gwilym Evans, unpublished data).

Selective effect of environmental factors

A considerable amount of evidence is accumulating on the selective effect of environmental factors on the variation which exists within herbage varieties. Sylvén (1937) demonstrated the rapid adjustment to climatic or biotic factors during seed multiplication of varieties of red and white clover, timothy and fescue in Sweden. Smith and Graber (1950) and Smith (1955) working in U.S.A. with Ranger lucerne found that one generation of increase in the south resulted in a higher ratio of tall to short plants in the population. In addition, following early autumn cutting in the south, the population was more susceptible to winter injury than when multiplied in the original area of adaptation. These differences became even more marked after a second generation in the south. Smith (1958) found a similar trend in other varieties of lucerne when grown at different latitudes; the trend could be reversed if the cultivars were grown considerably north of their point of origin. Shift in red clover is also referred to by Wexelsen (1932) and by Valle and Garrison (1959). Further work on this species at a series of locations in Canada is reported by Greenshields and McLennan (1960).

There are numerous characters within varieties on which selection pressures can operate. Donald (1959) in a study of subterranean clover points out the specific survival value of late-flowering plants under conditions encountered at high altitudes such as the alps of S.E. Australia, and of the high parts of the plateau in Spain. In subterranean clover, Black (1960) found petiole length to be important for survival when he investigated the effect of light interception on competition between plant types grown in swards. Demkin and Tselik (1957) point out how a change in the date of sowing clover and the seed harvesting system could alter the type of clover. These workers propose late sowing with subsequent killing of summer forms, and taking seed only in the second and third harvest year as a means of improving forage production. Barbacki and Rzegocinska (1960) found that a spring sowing of winter vetch (*Vicia villosa*) even for one year changes the population to a great extent, destroying winter and partially intermediate types in favour of spring types.

In Ladino clover, photoperiod, temperature and competitive ability affected the seed production of selected clones (Laude, Stanford and Enloe, 1958). In studies of *Agrostis tenuis* Bradshaw (1959) found close physiological adaptation to environment, and distances of 50 m. or less were sufficient effectively to differentiate

populations from one another. Plants that were able to survive under one set of conditions were very different physiologically from those only short distances away.

Selective effect of management

In the course of collections of potential breeding material from different habitats Stapledon (1922) and Jenkin (1943) have shown that plant types on average are morphologically characteristic of the environment from which they were derived. There has been considerable speculation as to the speed with which such adaptation to environment takes place, and recent work at Aberystwyth has thrown some light on this problem.

In a recent experiment mixtures were made of cultivars within ryegrass, cocksfoot and timothy, bred at Aberystwyth for different agronomic purposes. S.23 is an example of a variety within ryegrass well adapted for survival when frequently defoliated by the grazing animal, whereas among timothy varieties Bd 2308 is suitable for use under lenient defoliation in leys managed for hay or silage. The mixtures of cultivars within a species were subjected during establishment to a range of managements.

As most outbreeding herbage varieties are based on a number of unrelated plants, mixtures for re-seeding to grass contain a range of genotypes, and during establishment an enormous decrease in plant number occurs. In the current investigations, the plants surviving two months after sowing represented only 20% of the viable seed sown ; after 11 months only 10% remained (Charles 1961). These heavy casualties allow selection to occur in one direction or another, according to the specific pressures.

Data collected at various centres during the establishment of young leys, and from older swards, showed that selection of plant types occurred very quickly in response to grazing intensity, the application of nitrogenous fertilizer and the use of a cover crop. Thus the early-flowering erect cultivar Bd 2308 dominated the other timothy varieties in the sward when established under lenient defoliation, but made a significantly lower contribution to swards established under frequent grazing or when sown under a cover crop. Data taken from ryegrass swards indicate that one plant type can dominate another in a relatively short time. Mixtures of late-flowering S.23 ryegrass with each of the two early cultivars, Irish and S.24, were sown at an upland centre. Samples collected in the sixth harvest year showed that Irish and S.24 represented only 1% and 3% of the total ryegrass tillers, even though the early-flowering

cultivars showed good persistency when grown without competition from S.23.

The effect of management on the plant type surviving in a sward of one cultivar of cocksfoot has been studied. A leafy cocksfoot variety was sown broadcast with white clover and subjected to three managements for five years. The plants surviving in plots grazed very closely by sheep five times a year were later heading than those from plots cut by a mowing machine, either for hay and aftermath or mown each time the sheep had access to the grazed areas. (Plate 1, lower right.)

The evidence from the seed production experiments at the Station shows that the management of grass seed crops may profoundly influence the stability of a variety (Gwilym Evans, unpublished data). Bred varieties of tall fescue and late-heading timothy have shown an increase in the proportion of taller plants from a very heavy seed rate, and a decrease after late harvesting.

Defoliation at the time of inflorescence formation as a pretreatment of leafy varieties of cocksfoot and a late-heading timothy delayed floral emergence in the next generation, but not in early-heading varieties of perennial ryegrass, timothy and meadow fescue.

Conclusion

From the evidence produced at the Station it would appear that the degree of shift which might occur during seed multiplication of outcrossing herbage plants may vary according to the variety within the species.

Davies (1954) found that after six generations the late-heading S.23 perennial ryegrass came into head eleven days earlier, but Cooper (1959a) observed that when due care was taken in the production of each generation there was by the fifth generation only a slight shift towards earliness and that the type was well preserved in the stock received by the farmer.

In a late-flowering red clover W. Ellis Davies (unpublished data) could not detect differences between the third and tenth generations in respect of time of flowering, number of tillers, number of internodes, length of tillers, percentage survival, green weight and leaf markings. Williams (1923) observed a remarkable uniformity of type in seed crops of the old land variety Montgomery late-flowering red clover after seed crops had been taken from the *second* harvest year for many generations, a procedure which would tend to eliminate the early flowering, less persistent types.

The evidence is clear that in developing schemes for seed

multiplication there is a danger that the material supplied to the farmer may show a distinct shift in type from that originally released by the breeder. Instability has been shown to derive from several sources, apart from contamination by foreign pollen or gross mixing in the crop and/or during seed processing. In the production of certified seed of superior varieties measures should, therefore, be taken to reduce to a minimum a possible shift in type and to maintain the character of the variety.

Shift due to inherent factors such as differences in fertility and seed-producing potential among basic plants could be modified to some extent by a judicious control of the proportions of the basic plants constituting the original seed island. This may be conveniently done by clonal divisions, so that the seed harvested may be roughly equal for each clone. If the seeds from clones were kept separately it would be possible to determine the proportions of seed from each basic plant used for the production of the next generation as well.

Evidence has accumulated to show that when varieties are multiplied in areas with climatic conditions and day length widely different from those of the region of origin, a considerable shift in character may occur, even in the first generation. Where the shift is only slight, it may be convenient to grow the seed where the climate is more favourable for seed production. Even within the region of origin it has been shown at Aberystwyth that shift in a leafy variety of grass may be retarded to some extent by suitable management of the seed crop, such as by controlling the seed rate, appropriate defoliation, and harvesting the seed at a favourable stage of maturity.

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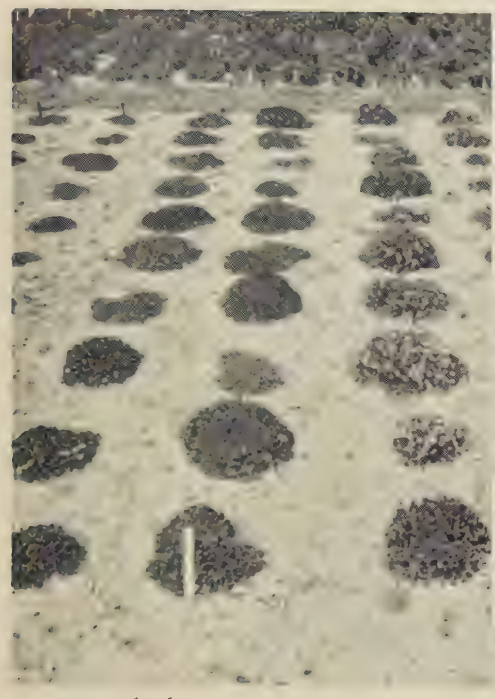

1st harvest year
Two rows (left) of plants derived from seed produced in Britain; one row from seed produced abroad.

2nd harvest year
Two rows of plants from seed produced in Britain (persistent); one row from seed produced abroad (non-persistent).

Plants from seed crops of S.143 cocksfoot grown and certified in U.S.A., compared with British grown and ordinary Danish.

Cocksfoot plants of the same variety derived from grazed plots (foreground), and cut plots (background).

Plate 2

Winter growth in cocksfoot at end of January.

1. Swedish diploid — all aerial parts dead.
2. Tetraploid cultivar — all aerial parts dead.
3. Portuguese diploid — green and leafy.
4. ,, ,, — plot growth compared to S.143 (right).
5. Early fodder cocksfoot plot growth compared to S.37 and Danish.

GRASS RESOURCES FOR OUT-OF-SEASON PRODUCTION

MARTIN BORRILL

One of the objectives of the herbage breeder in Britain is to provide varieties which will extend the production of herbage throughout the winter. A grass which is to give keep for grazing in December and January after being put-up in the autumn must continue to grow and produce green leaf, remain green and palatable, and not burn. For this reason the term keep is used in preference to foggage, as it is not simply bulk which is required, but good quality green leaf.

Where are such grasses to be found ? Data recently obtained for cocksfoot suggest an answer. Spaced plants from 72 collections from Europe and the Mediterranean were cut back in August, and at the end of the following January the percentage of green leaf on each was recorded (Appendix P. 112). The figures are averages for 1957 and 1958. On the map (Fig. 1) the black portion of each point shows the winter greenness of the collection from the place in question, and the white portion the amount of burn.

The figures show the proportion of green leaf irrespective of the amount of growth made during the period, nevertheless the introductions which burn most are also those which produce little growth after November.

Cocksfoot is not simply one grass, it includes several species. The commonly used agricultural cultivars are all based on the North European tetraploid (*Dactylis glomerata* subsp. *glomerata*) ; some of the others are diploids (Borrill 1961). On the map, localities enclosed in an outer circle are those where the winter growth of a diploid has been studied. These diploids can conveniently be used to illustrate the variation of winter growth at Aberystwyth in plants from different centres of origin. The photographs were taken in February 1958, when during the preceding 6 weeks the grass temperature fell below 27°F. on 19 days. The first photograph in Plate 2 (opposite) shows diploid plants from Sweden (*D. glomerata* subsp. *aschersoniana*), (Map ref. 66), completely burned, and the foliage bleached white ; they have little growth after November. A similar effect can be seen in a representative cultivar shown in the second photograph (Map ref. 20). This is typical of the reaction of varieties based mostly on plants originating in Britain and the more northerly parts of Europe. The third photograph shows the Portuguese diploid (*D. glomerata* subsp. *lusitanica*) which is very green and leafy.

Fig 1. Percentage of green growth present on populations of *Dactylis* grown at Aberystwyth relative to geographical origin.

Black section, percentage of green foliage
White „ „ burned „

Mean January isotherms (See Appendix for the location of the numbers on the map).

The isotherms for mean January temperature (Fig. 1) indicate that there is a broad correlation between winter temperature in the place of origin and winter production at Aberystwyth. The main factors influencing the seasonal growth cycle of herbage grasses are temperature and rainfall, and the stimulus of increasing or decreasing day length, which may have an effect in regions where there are definite contrasts between summer and winter growth.

The map shows that in cocksfoot from Central Europe, the aerial parts of the plant die at the onset of winter, during which they will often be buried under a cover of snow. Rainfall is ample for growth during the remainder of the year, and their life cycle is, therefore, winter dormancy and summer production. In cocksfoot native to regions like Wales with a more equable winter climate with a mean January temperature over 40° F., and rainfall distributed fairly evenly throughout the year, there is still an appreciable degree of winter dormancy. In the Mediterranean area, mean January temperature in the more northerly and easterly parts is similar to, or a little higher than, that in Wales, and farther south it is is definitely higher (mean January temperature over 50°F.). The winters are mild with adequate rainfall, and the summers are hot and dry. The wild cocksfoot plants are adapted to winter growth and are dormant in summer. This behaviour persists when the plants are grown at Aberystwyth, although in the summer somewhat limited growth occurs instead of complete dormancy, suggesting that dormancy depends on the moisture available (Laude, 1953).

These observations at Aberystwyth reveal the close genetical adaptation of the wild grasses to the seasonal fluctuations of climate in the places where they grow wild. Their survival depends on this adaptation, and consequently the winter growth of grasses native to Britain and Northern Europe is conservative. This growth pattern, which appears to be optimal for survival of the grass, is completely different from what the farmer requires, namely, grasses which will produce green fodder in the winter.

The map shows that green, winter-growing material is to be found farther south in areas with mild winters thus allowing of productive growth, and where the summers are not too dry, and so avoiding too strong a tendency to summer dormancy. Amongst such areas we may include Central Portugal, where the mean January temperature is over 50°F. In the river valleys and on the mountains sufficient moisture is available during the summer.

Other promising areas are S. W. France and in the mountains of N. Africa.

At the Welsh Plant Breeding Station two cocksfoot varieties are being developed, each based on material from more southerly latitudes :

(1) *Portuguese diploid*: Observations on spaced plants of this diploid (map ref. 61) made since 1955 show that they are very winter-hardy and resistant to burn. Their seed fertility (333 seedlings per 100 spikelets) compares favourably with the average figures for tetraploid cultivars (62-288 seedlings per 100 spikelets, based on Stapledon 1931). They are also very vigorous, luxuriant and quite different from Portuguese tetraploids, which are generally of the smaller growing Mediterranean type (*D. glomerata* subsp. *hispanica*). This diploid is a close relative of the ancestors of all cocksfoot grasses, and is a primary source of vigour and winter growth.

The seasonal production of the material can provisionally be assessed from the results of a trial with S.143, and N.Z. Grasslands, as controls. Plots were sown with cocksfoot and white clover in April 1959, grazed for two days after 28 August, given 3 cwt. of complete fertilizer and put-up on 16 September. Three plots were grazed and sampled in mid-December 1959, 3 in mid-January 1960,

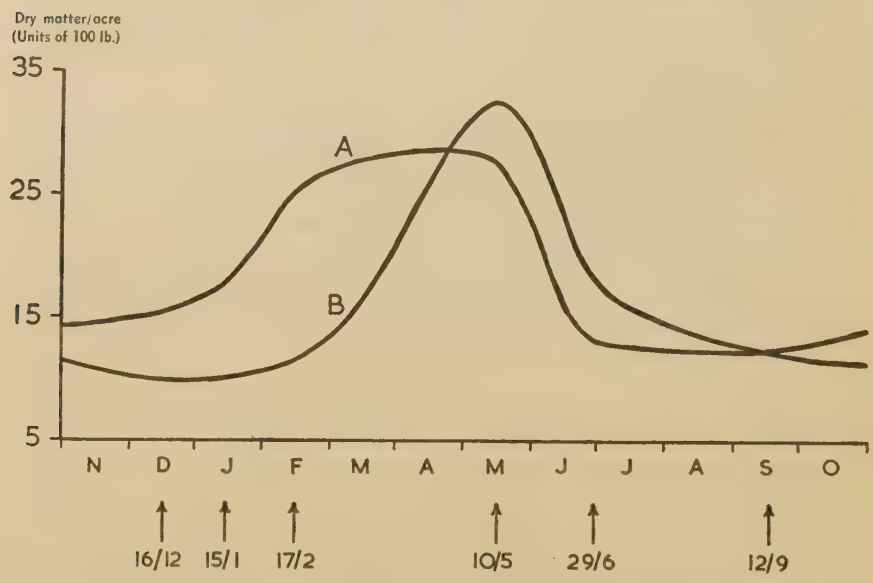

Fig 2. Seasonal growth rhythm of Portuguese diploid (A) compared with S.143 (B). Based on six plot sampling dates.

and 3 in mid-February. Dry matter production in the diploid increased from October onwards, and by mid-January it yielded over twice as much as the control varieties. The bulk of leafy growth at this date can be seen in the fourth photograph in the plate.

The subsequent production of all the plots was assessed by sampling on 10 May, 29 June, and 12 September. The production of the diploid, though still good, was exceeded by S.143 from the beginning of May. The total yearly dry matter production showed no differences due to treatment, or between varieties. The seasonal growth pattern of the diploid compared to S.143 as control is shown in Fig. 2. The diploid is superior up to the beginning of May, the excess production by S.143 from May to September is balanced by the additional growth of the diploid in autumn and winter.

(2) *Early fodder cocksfoot*: This variety has been developed by Mr. A. R. Beddows by selection amongst plants derived from seed-heads collected in south-west France, about 5° lat. south of Cornwall. It provides early spring keep, beginning active growth during March, in advance of either Danish or American cocksfoot, as may be seen in photograph number five in the plate.

This study of cocksfoot shows that great increases in productive potential for specific purposes can be obtained by the introduction of plants from suitable climatic areas. From this raw material, varieties with good out-of-season growth can be developed much more quickly than would be possible by re-selection within existing cocksfoot cultivars from N. Europe, which are based on wild plants which evolved in areas where low winter production is optimal for survival.

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APPENDIX

Origin of material for winter growth studies

Country	*Map ref.*	*Locality*	*Accession Nos.*		*Winter growth reaction. Per cent green leaf*	*Chromosome No. 2n =*
			W.P.B.S.	*F.A.O.*		
Algeria	1	Oued Chiffa	Bc 4458	3215	60	14
	2	Bouira	Bc 4463	3328	50	14
	3	Mansoura	Bc 4461	3252	60	28
	4	Medea	Bc 4459	3221	50	28
	5	Maillot	Bc 4460	3248	70	28
	6	Mascara	Bc 4456	3192	70	28
	7	Timgad	Bc 4462	3277	60	28
	8	Zemmora	Bc 4438	3168	90	14
Austria	9	—	Bc 3383	—	10	28
Cyprus	10	Northern hills†	Bc 2897, 3726 3728, 3730 3738–40, 3943 4175–6, 4181–4	—	91	28
Denmark	11	Borkop†	Bc 4141–4154	—	51	28
Eire	12	Co. Monaghan	Bc 4195, 4200–1	—	80	28
	13	Co. Meath	Bc 4197	—	90	28
	14	Slane	Bc 4199	—	90	28
	15	Dublin	Bc 4203, 4208	—	90	28
	16	Cork	Bc 4209	—	100	28
Britain	17	Cornwall	Bc 3135	—	77	28
	18	Eastbourne	Bc 4125	—	50	28
	19	Anglesey	Bc 2716	—	40	28
	20	Mid-Wales†	Bc 4360–69	—	75	28
Finland	21	Mikkeli	Bc 4186	—	0	28
	22	Helsinki	Bc 4187	—	20	28
	23	Yokioinen	Bc 4188	—	50	28
	24	Polkane	Bc 4192	—	40	28
	25	Knopio	Bc 4190	—	0	28
	26	Pukkio	Bc 4191	—	55	28
	27	Tokmajarvi	Bc 4189	—	35	28
	28	Ylistaro	Bc 4193	—	35	28
France	29	Le Trayas	Bc 3932	—	94	28
	30	Bordeaux	Bc 3563	—	40	28
	31	Rochefort	Bc 3566	—	60	28
Germany	32	Silesia	Bc 3372	—	10	28
Greece	33	Mandra	Bc 4518	3621	80	28
	34	Mazi	Bc 4519	3622	70	28
	35	Erythryae	Bc 4520	3628	70	28
	36	Domokos	Bc 4521	3638	80	28
	37	Mt. Mitsikeli	Bc 4523	3647	70	28
	38	Yannina	Bc 4524	3664	60	28
	39	Agrinion	Bc 4525	3674	50	28
Holland	40	Wageningen†	Bc 4216, 7, 9 Bc 4222 Bc 4225 Bc 4221	—	61	28

Country	Map ref.	Locality	Accession Nos. W.P.B.S.	Accession Nos. F.A.O.	Winter growth reaction. Per cent green leaf	Chromosome No. 2n =
Iran	41	Arak, Isfahan	Bc 4527	3696	50	28
	42	Eskon	Bc 4528	3700	50	28
	43	Schanach	Bc 4529	3724	40	28
	44	Firsuku	Bc 4532	3765	60	28
	45	Yek el Chinar, Prov. Khorassan	Bc 4355	—	40	14
Israel	46	Matzuba, Galilee	Bc 4037	—	90	28
	47	Jerusalem	Bc 4302	—	70	14
Italy	49	Renda, Monreale	Bc 3937, 39 40	—	90	28
	50	San Nicola, Enna	Bc 3942, 45, 47	—	96	28
	51	Rome, prealpi pasture	Bc 4015	—	60	28
Morocco	52	Grand Atlas	Bc 3930	—	100	28
	53	Tangiers	Bc 4126	—	97	28
	54	Tarou Dannt	Bc 4473	3372	80	28
Norway	55	Tjotta†	Bc 4161–73	—	40	28
Portugal	56	Sacavem	Bc 3959	—	100	28
	57	Sezimbra	Bc 4295	—	95	28
	58	Algueirao	Bc 4293	—	98	28
	59	Azenhas do Mar	Bc 4291	—	100	28
	60	Nazare	Bc 4296	—	100	28
	61	Sintra†	Bc 3948 3953, 54 57, 4292	—	98	14
Scilly Is.	62	St. Mary's	Bc 3171	—	70	28
Scotland	63	Queensferry†	Bc 4231, 33 36, 38, 41 Bc 4246, 48, 50 Bc 4256–58	—	71	28
Sicily	64	Palermo†	Bc 4044, 48 Bc 4950, 56 62, 68	—	93	28
Spain	65	Huesca	Bc 4372	—	90	28
Sweden	66	Uppsala	Bc 2911	—	35	14
	67	Stockholm Prov.	—	—	20	28
Turkey	68	Taliva	Bc 4035	—	80	28
	69	Can, Çannakalé	Bc 4353	—	80	14
U.S.S.R.	70	Georgian Rep.	Bc 4649	—	30	28
	71	Azerbaijan Rep.	Bc 4650	—	30	28
	72	Sub-Carpathian district	Bc 4648	—	10	28
	73	Kabardin Aulon Rep.	Bc 4647	—	0	28
	74	Moscow	Bc 4688	—	0	28
	75	Leningrad	Bc 4687	—	0	28
	76	Tomsk district	Bc 4644	—	0	28

† Collection includes populations from several habitats.

THE EFFECTS OF PLANT DENSITY AND FERTILIZER ON YIELD IN MARROW-STEM AND CANSON KALES

T. D. Johnston

The kales are widely recognized as crops capable of giving a marked response to generous dressings of nitrogenous fertilizer. In current farming practice they may be sown either broadcast at about 6–8 lb./acre or drilled in rows at approximately half this seed rate or, with the increasing popularity of precision drilling, may be spaced at predetermined intervals, thereby reducing the seed rate to less than 1 lb./acre.

The present investigation was undertaken to observe the reaction of kales to varying plant densities at different levels of fertility, and also to compare the results from two widely different types of kale to obtain information of possible value in the routine breeding and testing of these crops. One variety of marrow-stem kale of average type and one of Canson thousand-headed were selected as appropriate material for two main reasons, first, both are widely grown on farms, and second, they represent two extreme morphological types. Marrow-stem kale is a tall-growing, unbranched plant with a thickened stem which constitutes a major proportion of the total yield of the plant, whereas Canson is short, highly branched and has an almost inedible stem.

The trials with marrow-stem kale were carried out in 1957 and 1958 and with Canson kale in 1958 and 1959. All trials were closely similar in design, except for certain differences in levels of fertilizer application. The statistical lay-out was a split plot design with fertilizer treatments as main plots and three levels of plant density as sub-plots within each main plot, and there were three to four replicates.

Seed was sown in May of each year in drills 2ft. apart on land which had previously received a liberal dressing of farmyard manure plus 2 cwt./acre of complete fertilizer on the seed bed. At the two-leaf stage the plants were carefully singled by hand to give either 1, 2, or 4 plants per foot of drill (approximately 22,000, 44,000 and 88,000 plants/acre). Shortly after this operation Nitro-Chalk was applied at 0 (control), 30, 60 or 120 lb. per acre (elemental N) except for marrow-stem kale which had three dressings.

The marrow-stem kale was harvested in December and the Canson in late January. Each plot was cut after removal of border rows, the leaf and stem fractions were separated by hand, and

weighed for the estimation of yield of stem and leaf, total yield per acre, and percentage leafiness.

Marrow-stem kale

The yields obtained in the 1957 and 1958 trials are shown in Tables 1 and 2, and the percentage leafiness data for both trials in Table 3. The trend was similar in both seasons, the main difference being the greater yield obtained on the control plots in 1958 due to better soil fertility and possibly also to seasonal differences. The data will be discussed, therefore, with special reference to Table 2 in which a greater range of fertility levels is represented.

Table 1. *Yields of leaf and stem of marrow-stem kale (tons/acre fresh material) at 3 levels of fertility and 3 plant densities.*

1957

Plants/ft.	*Leaf* N.lb./acre				*Stem* N. lb./acre			
	0	30	60	*Mean density*	0	30	60	*Mean density*
1	3.53	3.81	4.51	3.95	4.29	5.20	6.13	5.21
2	4.62	5.75	6.43	5.60	5.89	7.74	10.64	8.09
4	5.32	5.95	5.87	5.71	6.53	8.01	10.13	8.22
Mean N. level	4.49	5.17	5.60		5.57	6.98	8.97	

Table 2. *Yields of leaf and stem of marrow-stem kale (tons/acre fresh material) at 3 levels of fertility and 3 plant densities.*

1958

Plants/ft.	*Leaf* N. lb./acre				*Stem* N. lb./acre			
	0	60	120	*Mean density*	0	60	120	*Mean density*
1	1.86	3.84	6.87	4.19	1.29	3.94	8.87	4.70
2	2.63	5.10	6.59	4.77	1.89	4.87	9.86	5.54
4	3.37	5.78	6.89	5.35	2.47	6.57	10.35	6.46
Mean N. level	2.62	4.91	6.78		1.88	5.12	9.69	

Sig. diff. P=0.05

Fertilizer means 0.641 tons	Fertilizer means 0.953 tons
Density means 0.581 ,,	Density means 0.671 ,,

Yield of leaf

As the dressings of Nitro-Chalk became heavier the mean yield of leaf at all densities increased considerably and was significantly different at the 1% level of probability. Similarly the mean yields for the three levels of density showed a significant, though much smaller, rise with increasing plant population. The most interesting

and important feature, however, was the apparent interaction between these two sets of factors.

Although not quite statistically significant at $P = 0.05$ the figures indicated certain trends. It can be seen that the greatest increase in leaf yield with increasing plant density occurred at the lowest fertility level, and that the greatest increase in yield with increasing applications of fertilizer occurred at the lowest plant density. In the 1958 experiment there was no effect on leaf yield due to variations in plant density at the highest fertility level. The yield of nearly 7 tons/acre at this level, irrespective of plant density, probably represented a physiological limit at which maximum leaf cover had been attained for the conditions of environment, variety and time of harvest imposed on the material, and at which leaf development was fully compensated by loss of the older, heavily shaded leaves.

Yield of stem

The yield of stem showed a similar variation to yield of leaf. The increase due to the dressing of fertilizer, however, was much more marked, and within the range of treatments employed, there was always a small advantage in favour of the higher density at any fertility level, with no evidence of a yield ceiling having been attained.

Table 3. Percentage leaf of marrow-stem kale (fresh material) at 3 levels of fertility and 3 plant densities.

Year	1957				1958			
	(*lb./acre N.*)				(*lb./acre N.*)			
Plants/ft.	0	30	60	*Mean density*	0	60	120	*Mean density*
1	45.4	43.2	43.5	44.0	56.8	49.3	44.0	50.0
2	44.5	41.9	38.8	41.7	57.5	51.3	40.8	49.8
4	44.8	41.4	36.9	41.0	57.5	47.5	40.0	48.3
Mean N. level	44.9	42.1	39.7		57.3	49.3	41.6	

The reaction of leaf and stem to the various treatments is well illustrated in Table 3. The figures show that there was very little effect on the percentage leafiness due to variations in plant density, but that there was a considerable fall with increasing fertility due to the relatively greater response of stem growth.

Canson kale

The same treatment was applied to replicated trials of Canson kale in 1958 and 1959 ; the yields per acre of green matter of leaf and stem obtained in the two years are given in Tables 4 and 5.

Table 4. Yields of leaf and stem of Canson kale (tons/acre fresh material) at 4 levels of fertility and 3 plant spacings.

1958

	Leaf (*lb./acre N.*)					*Stem* (*lb./acre N.*)				
Plants/ft.	0	30	60	120	*Mean density*	0	30	60	120	*Mean density*
1	1.60	3.85	4.89	5.18	3.88	0.56	1.41	1.67	2.20	1.46
2	2.12	5.12	5.87	6.29	4.85	0.93	1.86	2.43	3.13	2.09
4	3.34	4.86	6.22	6.36	5.19	1.42	2.13	2.72	2.62	2.47
Mean N. level	2.35	4.61	5.66	5.94		0.97	1.80	2.27	2.98	

Table 5. Yields of leaf and stem of Canson kale (tons/acre fresh material) at 3 levels of fertility and 3 plant densities.

1959

	Leaf (*lb./acre N.*)					*Stem* (*lb./acre N.*)				
Plants/ft.	0	30	60	120	*Mean density*	0	30	60	120	*Mean density*
1	4.27	5.98	7.19	9.28	6.68	2.28	3.79	4.51	6.00	4.14
2	5.12	6.48	7.45	8.96	7.01	3.09	4.07	5.54	6.39	4.77
4	5.28	7.09	7.68	8.72	7.19	3.56	4.87	6.64	7.00	5.51
Mean N. level	4.90	6.52	7.44	8.98		2.97	4.24	5.56	6.46	

Sig. diff. (P=0.05)

Fertilizer means	0.646 tons
Density means	0.466 ,,
Fertilizer means	0.691 tons
Density means	0.455 ,,

The general trend of the results in both years was closely similar, though the inherent fertility of the soil in 1959 was much higher and there was less damage in that year from insect pests.

Yield of leaf

There was considerable response at all plant densities to the application of fertilizers. The small variations due to density at any one fertility level or over all levels did not reach significance in the 1959 trial, and there was no significant interaction between the two sets of treatments. The effect of increase in density, however, appeared to have been reversed at the highest fertility level. This probably represents a real effect, because a visual examination of the material in the field indicated that growth at this level of fertility was luxuriant, and at the close spacing the inter-plant competition had led to almost complete suppression of lateral branching which is normally an important feature of this variety of thousand-headed kale. In the more widely spaced material there

was still considerable formation of side branches and therefore a more rapid leaf production.

Yield of stem

The yield of stem, from the practical point of view of negligible feeding value, showed a steady increase at the higher plant density, and the heavier applications of fertilizer, with no apparent interaction over the range of treatments. The relative increase, however, was less than in marrow-stem kale, thus leading to smaller changes in percentage leafiness (Tables 3 and 6).

Table 6. *Percentage leaf (fresh material) of Canson kale.*

Plants/ft.	1958 (*N. lb./acre*)				*Mean density*	1959 (*N. lb./acre*)				*Mean density*
	0	30	60	120		0	30	60	120	
1	74.3	72.3	74.5	70.0	72.8	65.4	61.6	61.6	60.8	62.4
2	69.3	71.8	71.0	66.8	69.7	62.7	62.8	57.5	58.5	60.2
4	70.0	69.0	69.5	64.0	68.1	60.1	59.3	54.3	55.5	57.3
Mean N. level	71.2	71.0	71.7	66.9		62.8	61.1	57.8	58.2	

Discussion

The results of these trials indicate that the several forms of agricultural kale react quite differently to variations in soil fertility and plant spacing. The differences involve both actual yields of the stem and leaf fractions, and changes in leaf : stem. It is necessary therefore to consider the implications in relation to breeding and practical crop husbandry.

For selection and testing of crop varieties it is desirable to carry out tests under conditions comparable to good farm practice which, with the kales, implies reasonably high fertility conditions. In the present investigation it was found that at high fertility the yield characteristics of the two varieties tested were very uniform over the range of plant densities used. Thus it appears that for potentiality trials of *Brassicae*, provided the fertility level is high, small variations in plant density will have negligible effect on yield of leaf and stem. Density, however, can have an effect on morphological appearance (degree of branching) and this needs to be taken into consideration when selecting breeding material.

From the practical crop husbandry aspect, a number of important points emerge. First, large crops cannot be grown whatever the plant density if the soil is poor, although at low fertility there is considerable advantage in favour of the denser crop. At

better fertility levels there is virtually no difference in yield of leaf of marrow-stem kale between quite wide density limits, although the stem yield may be slightly more at high density. There is, however, another important consideration in that the individual stems in a widely-spaced crop may become too large for good utilization *in situ*.

Canson kale under high fertility appears to have the advantage when grown as a widely-spaced crop because of the totally different growth habit of the plant. Wide spacing allows of better development of the lateral branches, with good leaf : stem. The crop height is reduced, and this automatically minimizes the problem of stem disposal after grazing. The short, ' compact ' crop is also more suited to consumption *in situ* by sheep, and appears to be a little more resistant to low temperature because of the mutual protection afforded by the densely crowded shoots.

Conclusion

The experiments have shown that there is little difference in yield between plant spacings of 1–4 plants per ft. in rows 2 ft. apart, provided fertility is high and the crop has had an adequately long growing season. Close spacing appears to facilitate the utilization *in situ* of marrow-stem kale, and wider spacings that of the Canson kale.

As a study of breeding material, however, the experiments have demonstrated that variations in plant density and fertility level can have marked effects upon the morphological form of the plants, and this should be borne in mind when comparisons are being made between kales of differing types. Under the moderately high levels of fertility normally employed, the total yield and leaf : stem remain fairly constant over a wide range of plant densities. At lower levels of fertility the effects of variation in density become much more apparent, and valid results could be expected only by standardizing plant density.

THE INFLUENCE OF SOME EDAPHIC FACTORS ON THE GROWTH AND DISTRIBUTION OF GRASSES

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There is comparatively little experimental evidence relating to the part played by edaphic factors in determining the distribution of grass species in Great Britain, particularly concerning the response of species to pH, mineral elements at toxic concentrations and the low availability of nutrients. The work briefly reported in this article is an attempt to provide some such information and thereby help towards a better understanding of the way in which soils can determine the distribution and growth of different grasses.

In the first instance an experiment was set up to determine the influence of pH on the growth of *Nardus stricta*, *Molinia caerulea* and *Lolium multiflorum* var. *westernwoldicum*, three grasses with widely different ecological preferences. The species were grown for 8 weeks in culture solutions with mean pH values of 3.75, 6.75 and 7.85 and also on a John Innes No. 1 Potting Compost to one lot of which was added 2.5% by weight of calcium carbonate ($CaCO_3$). The pH of these two soils was 5.6 and 8.3. Table 1 gives the weight of shoots at the end of eight weeks.

Table 1. *Mean dry weight of shoots* (*gm.*)

	Culture solutions				*John Innes Compost*		
	pH 3.75	6.75	7.85	*L.S.D.* $P=0.05$	*Unmodified* *pH* 5.6	+ $CaCO_3$ 8.3	*L.S.D.* $P=0.05$
M. caerulea	2.21	2.25	1.46	0.45	1.48	0.01	
N. stricta	0.35	0.65	0.27	0.11	0.81	0.005	
L. multiflorum var. *westernwoldicum*	3.65	5.94	2.00†	1.99	4.97	5.51	0.80 gm.

† Plants dead when harvested

All the plants in the culture solution were healthy except *Lolium* at pH 7.85. In the John Innes No. 1 Compost the three species thrived, but where calcium carbonate had been added, *Lolium* grew luxuriantly, while *Molinia* and *Nardus*, although remaining green, made negligible growth. It is seen from the data that the three species can grow successfully in conditions where the pH of the medium is very different from that of the soils in which they normally

grow. This suggests that some of the effects obtained such as poor growth of *Nardus* and *Molinia* on calcareous soil, may be related more to the response the species made to the chemical nature of the growth medium, rather than to any direct influence of pH on growth.

The mineral content of the plants was determined and the figures for phosphorus and iron are given in Table 2.

Table 2. Phosphorus and iron content of shoots expressed as mgm./gm. dry weight.

	Culture solutions							*John Innes Compost*			
	Phosphorus				*Iron*			*Unmodified*	*Unmodified + $CaCO_3$*	*Unmodified*	*Unmodified + $CaCO_3$*
	pH	3.75	6.75	7.85	3.75	6.75	7.85	*pH*	*Phosphorus* 5.6	8.3	*Iron* 5.6	8.3
M. caerulea		5.02	3.72	3.43	0.19	0.13	0.23		1.78	0.42	0.14	0.17
N. stricta		5.87	5.01	5.53	0.66	0.65	0.86		3.20	†	0.27	†
L. multiflorum var. *westernwoldicum*		2.38	2.40	3.00	0.43	0.24	1.03		1.35	1.17	0.17	0.23
L.S.D. $P=0.05$			0.79			0.22				0.20		0.03

† Insufficient plant material for analysis

The plants of *L. multiflorum* var. *westernwoldicum* that died in the alkaline culture solution showed no sign of chlorosis, and the most likely explanation is that they suffered from iron toxicity, as the analysis showed an extraordinarily high iron content. Olsen (1958) working with hemp (*Cannabis sativa*), a calcicole, found that plants often suffered from iron toxicity when grown in alkaline culture solutions. He considers this to be the natural consequence of calcicole plants adapting themselves to calcareous soils which are normally very low in available iron. Presumably such plants are very efficient at obtaining iron from the soil, and if they are grown in conditions where iron is readily available they may well take up so much as to render the element toxic.

In a similar manner, we may account for the high phosphorus and iron content of *N. stricta* compared with *M. caerulea* and *L. multiflorum* var. *westernwoldicum*. *N. stricta* is usually found on soils low in phosphorus and rich in available iron, and this species may well have developed an efficient mechanism for obtaining phosphorus from the soil and at the same time have acquired a tolerance to a high internal iron concentration.

One of the interesting problems posed by the data is why *Molinia* and *Nardus* made virtually no growth in the John Innes No. 1 Potting Compost to which had been added calcium carbonate, while *Lolium* grew luxuriantly (Table 1). The data giving the

phosphorus content of the three species (Table 2) showed a marked decrease of this element in *Molinia* on the John Innes No. 1 Potting Compost + $CaCO_3$ and it could be that *Molinia* is unable to obtain the phosphorus in a freely-drained calcareous soil. Rorison (1960) has indicated that calcifuge plants may have difficulty in obtaining phosphorus in calcareous soils. In order to test this hypothesis *Molinia* was grown in soil containing free calcium carbonate as used in the first experiment, but at the same time the phosphate level in one lot of soil was increased forty-fold by the addition of triple superphosphate (Table 3).

Table 3. *Mean shoot weight of* Molinia : *dry matter* (*gm.*)

		+	+
	J.I. No. 1	$CaCO_3$	$CaCO_3$ + *Phosphate*
pH	5.6	8.3	8.0
	6.42	0.05	5.32

L.S.D. *P* at 0.05 = 1.01 gm.

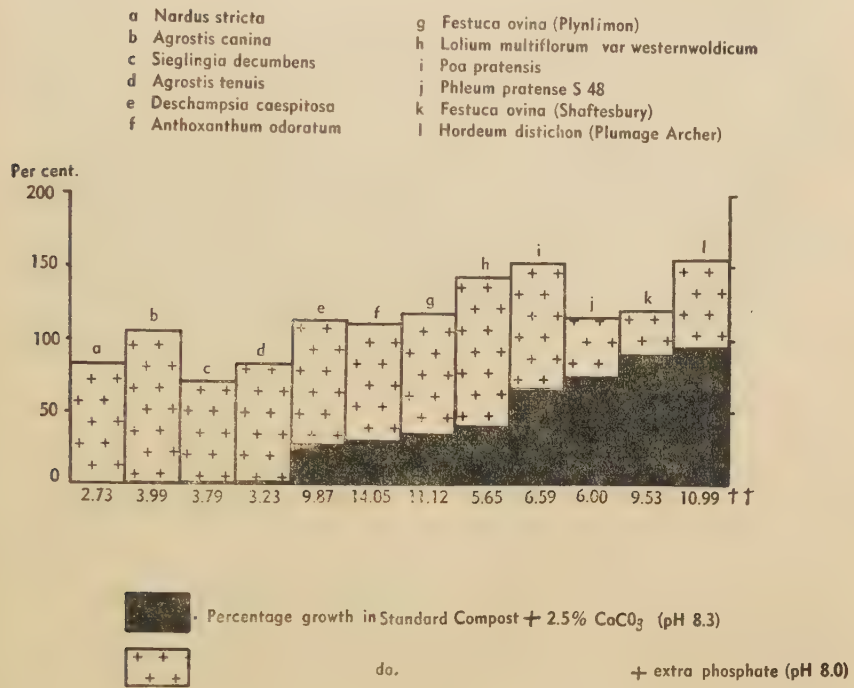
These results show that high levels of calcium carbonate in the soil adversely affect the growth of *Molinia,* but this inhibitory effect of free calcium carbonate can be overcome by the addition of extra phosphate. Thus it would seem that *Molinia* is unable to grow on freely-drained calcareous soil as the plant cannot obtain sufficient phosphate from it.

Later it was decided to test the response of a number of grasses in the soil treatments used in Table 3. Two populations of *F. ovina* were used, one from chalk downland near Shaftesbury, Dorset, and the other from Plynlimon. The shoot fresh weight of the species in the soil treatments is indicated in Fig. 1 on next page.

The species growing in the three soils prepared from the John Innes No. 1 Potting Compost appeared healthy and there was no trace of chlorosis. It will be seen that the addition of calcium carbonate depressed the growth of the species, in particular the calcifuge plants, *N. stricta, A. canina, S. decumbens, A. tenuis.* This inhibition of growth, however, could be very largely overcome by the addition of extra phosphate.

We must conclude from the data that the so-called calcifuge grass species can grow and flourish in calcareous soils with a very high pH value, and that neither high pH nor high calcium levels in themselves restrict the growth of these species. It would seem that

Fig. 1. Mean shoot weight of species grown in two soils expressed as a percentage of their growth in Standard compost†.



† John Innes No. 1 Compost Mixture

†† Mean shoot weight (gm.) of species grown in unmodified Standard Compost (pH 5.6)

such species are excluded from calcareous soils because of their inability to obtain phosphorus. This poses the very intriguing problem of why some species can obtain phosphorus from calcareous soils while others can not.

It is difficult to say to what extent unavailability of phosphorus excludes calcifuge species from calcareous soils under natural conditions. The lack of essential nutrients such as iron is known to be an important factor restricting the growth of these plants, (Rorison 1960). It would seem, however, that even when iron is available in a calcareous soil the growth of many species is restricted, due to their inability to obtain phosphate.

It must be emphasized that no single factor is likely to explain

the growth response and distribution of any one species in relation to the soil. Whether a plant flourishes or not depends on the critical balance of all the contributing factors two of which are the ability to obtain phosphorus under various conditions and the resistance to elements at toxic concentrations.

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METEOROLOGICAL FACTORS AND ANTHESIS OF GRASSES

TIBOR I. EMECZ

This brief report summarizes data collected on plants in pots kept under natural meteorological conditions during the three years 1957–59. The following grasses were included: *Lolium perenne* S.24, S.101, S.23, Irish commercial and an indigenous variety ex France; *Dactylis glomerata* S.26, S.37, S.143; *Phleum pratense* S.51, S.48, Bd. 2308; *Phleum nodosum* S.50; *Alopecurus pratensis* S.55; *Festuca arundinacea* S.170; *Festuca pratensis* S.215; *Festuca rubra* Georgicon bred variety ex Hungary; *Festuca ovina* S.58. Temperature, relative air humidity, and light intensity were recorded in the immediate vicinity of the plants at plant-base level, and wind velocity at 9 ft. above ground.

Four factors were found to regulate anthesis in the observed grasses; temperature and light intensity had positive effects by inducing and promoting anthesis, wind velocity and precipitation could hinder or even inhibit it. Relative air humidity had no measurable effect except when it caused altered light conditions, or when it was accompanied by precipitation. These four factors have to exceed a threshold value before they can become effective, and remain above it for a definite period to induce or to inhibit anthesis. The required duration of action as well as the threshold value varied with the species and the varieties. For example, the threshold values for S.24 were 57°F. temperature and 2000 ft. c. light intensity with 2.5 hours' duration, whereas for S.23 they were 62°F. and 4400 ft. c. for 1.5 hours. Wind velocity at 15 m.p.h. inhibited anthesis in both cases. S.48 had 62°F. and 1200 ft. c. as threshold values, with 10 hours' duration; on the other hand, wind velocity at 8 m.p.h. inhibited anthesis. This variation in the requirements determines the flowering time within the day, consequently the daily flowering time also varies between species and within species. Different meteorological conditions caused variations in daily flowering time even within a variety. This is likely to occur if flowering takes place at unusual calendar dates, for example, in the aftermath or when plants of the same variety are cultivated in different locations, especially under different latitudes or altitudes.

The different requirements of individual genotypes cause slight but regular variations in their daily flowering time. These variations are greater in individuals which differ in their emergence date. Similarly for varieties, and therefore there are greater

differences between S.24 and S.23, or Bd 2308 and S.48, than between S.23 and S.101, or S.51 and S.48.

The results help to elucidate some previous findings. The reported variations in different countries in the flowering times of a given species at different latitudes or dates can be explained by the devious meteorological backgrounds.

The duration of anthesis (either within one day or within one inflorescence) and the liberation of pollen were influenced by the factors which produce induction. Clones in the glasshouse flowered sooner than those left outside and flowering occurred in the glasshouse on days when no flowering took place outside. These phenomena are due to differing meteorological conditions, and show that observations in the glasshouse are not always valid under natural conditions, and that even plants in pots outside may differ in flowering time from those in the field.

The rate at which anther exsertion takes place is consistent for each species. Those, which exsert their anthers relatively rapidly, as *Lolium perenne*, *Festuca arundinacea*, *F. pratensis*, *F. rubra*, *F. ovina*, are affected by the meteorological conditions immediately prior to anthesis. Others, like *Dactylis glomerata*, *Phleum pratense*, *P. nodosum*, *Alopecurus pratensis*, are mainly dependent on the weather conditions of the previous day. The latter groups have relatively longer filaments, and exsert their anthers in greater numbers at each anthesis time, and normally do so earlier in the day.

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